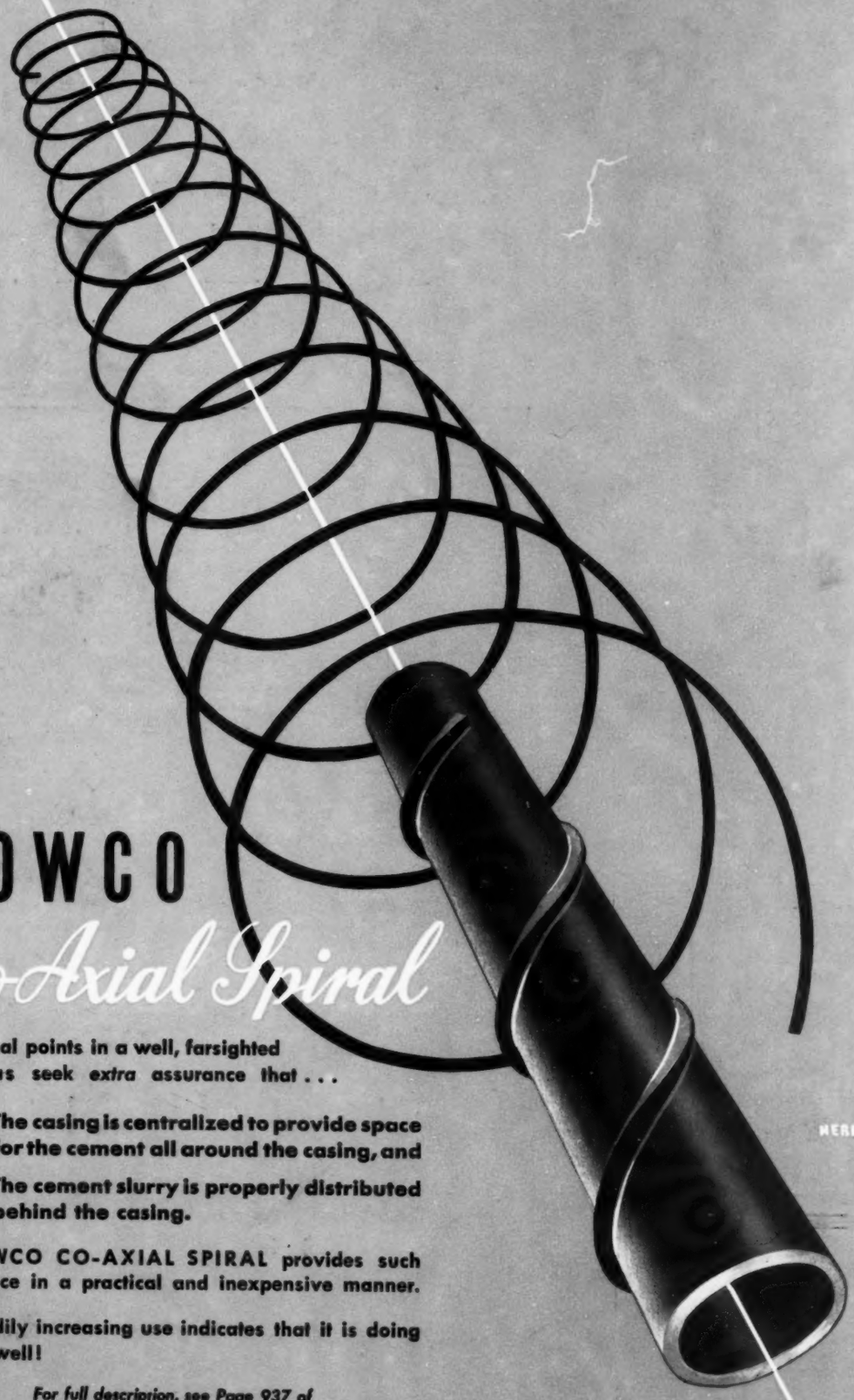
PROPERTY OF
CETON UNIVERSITY LIBRARY
RECEIVED JUL 20 1940

WORLD PETROLEUM

DRILLING and DEVELOPMENT

JULY 1940



HOWCO

Co-Axial Spiral

At critical points in a well, farsighted operators seek *extra* assurance that . . .

1. **The casing is centralized to provide space for the cement all around the casing, and**
2. **The cement slurry is properly distributed behind the casing.**

• HOWCO CO-AXIAL SPIRAL provides such assurance in a practical and inexpensive manner.

Its steadily increasing use indicates that it is doing its job well!

For full description, see Page 937 of your Composite Catalog.

HERBERT B HILL

HALLIBURTON OIL WELL CEMENTING CO.

WORLD PETROLEUM

RUSSELL PALMER
Publisher

E. W. Mayo
Editor

T. Orchard Lisle
Executive Editor

E. W. Mayo, Jr.
Managing Editor

S. J. Gallay
Advertising Manager

VOLUME 11 | **JULY, 1940** | **NUMBER 7**

WORLD PETROLEUM: Incorporating Petroleum Equipment Exporter

CONTENTS

War Intensifies Exploration in Europe 37

Drilling in South America . . . 42

Looking to the 20,000 Ft. Well . . 46

Huge Reserve in Present Producing Fields 54

Turner Valley 68

Geochemical Exploration . . . 72

Fluid Drive 81

Foreign Oil Legion 90

Abstracts of World's Oil Literature . 97

World Crude Production Tables . . 108

CORRESPONDENCE

ADDRESS all correspondence regarding editorial, advertising, subscription and business matters to the Home Office; 95 River Street, Hoboken, N. J. Telephone Rector 2-2043 or Hoboken 3-2480.

London office; 3 Savoy Place, Victoria Embankment, W.C.2.

Los Angeles office; 412 West 6th Street

SUBSCRIPTIONS

ANNUAL subscription to WORLD PETROLEUM is offered at the flat rate of five dollars (U. S.) postpaid to any country in the International Postal Union.

For the convenience of subscribers the publisher will accept payment in any of the following currencies at the fixed rate shown below:

Argentina	16 paper dollars
Canada	5.00 dollars
Colombia	5.00 pesos
France	190 francs
Germany	13 reichsmark
Great Britain	1 guinea
Netherlands	10 guilders
India	15 rupee
Iran	1 guinea
Iraq	1 guinea
Italy	95 lire
Japan	20 yen
Mexico	25 pesos
Peru	25 sol
Poland	27 zloty
Roumania	675 leu
Russia	6 roubles
Venezuela	15 bolivar

REMITTANCES or drafts should be drawn to the order of the Publisher, WORLD PETROLEUM, payable in New York and London.

Subscriber's name and address should be in Roman capitals on the subscription order.

Official position of subscriber is requested.

Advance notice, if possible, of a change of subscriber's address should be given.

AGENCIES

SINGLE copies of WORLD PETROLEUM are obtainable every month, within the delay imposed by the international mail service, at any of the following agencies:

BERLIN, 35, W. GERMANY—Verlag Chemie G.m.b. H. Corneliusstrasse 3.
MARACAIBO, VENEZUELA—High Life Tailors.
THE HAGUE, NETHERLANDS—Martinus Nijhoff, Lange Voorhout 9
LONDON—World Petroleum, 3 Savoy Pl., Victoria Embankment, W.C.2, telephone: TEMple Bar 1735
A. C. Hardy, 110 Fenchurch St. E. C. 3
W. H. Smith & Sons, Ltd., Moorgate Met. Station
Willing & Co., Ltd., Moorgate Met. Station
Barker & Howard, 6 Fenchurch Buildings, E. C. 3
NEW YORK—Telephone Rector 2-2043 for list of 20 newsstands carrying copies
PARIS—Librarie Brentano, 37 Avenue de l'Opera.
PORT OF SPAIN, TRINIDAD—Davidson & Todd, Ltd., 8 Frederick St.
LOS ANGELES—412 West 6th St., telephone: Mutual 1391.

British subscribers may make payments at the London office of World Petroleum. Monthly copies, two shillings; yearly, one guinea.

PARTICULAR NOTICES

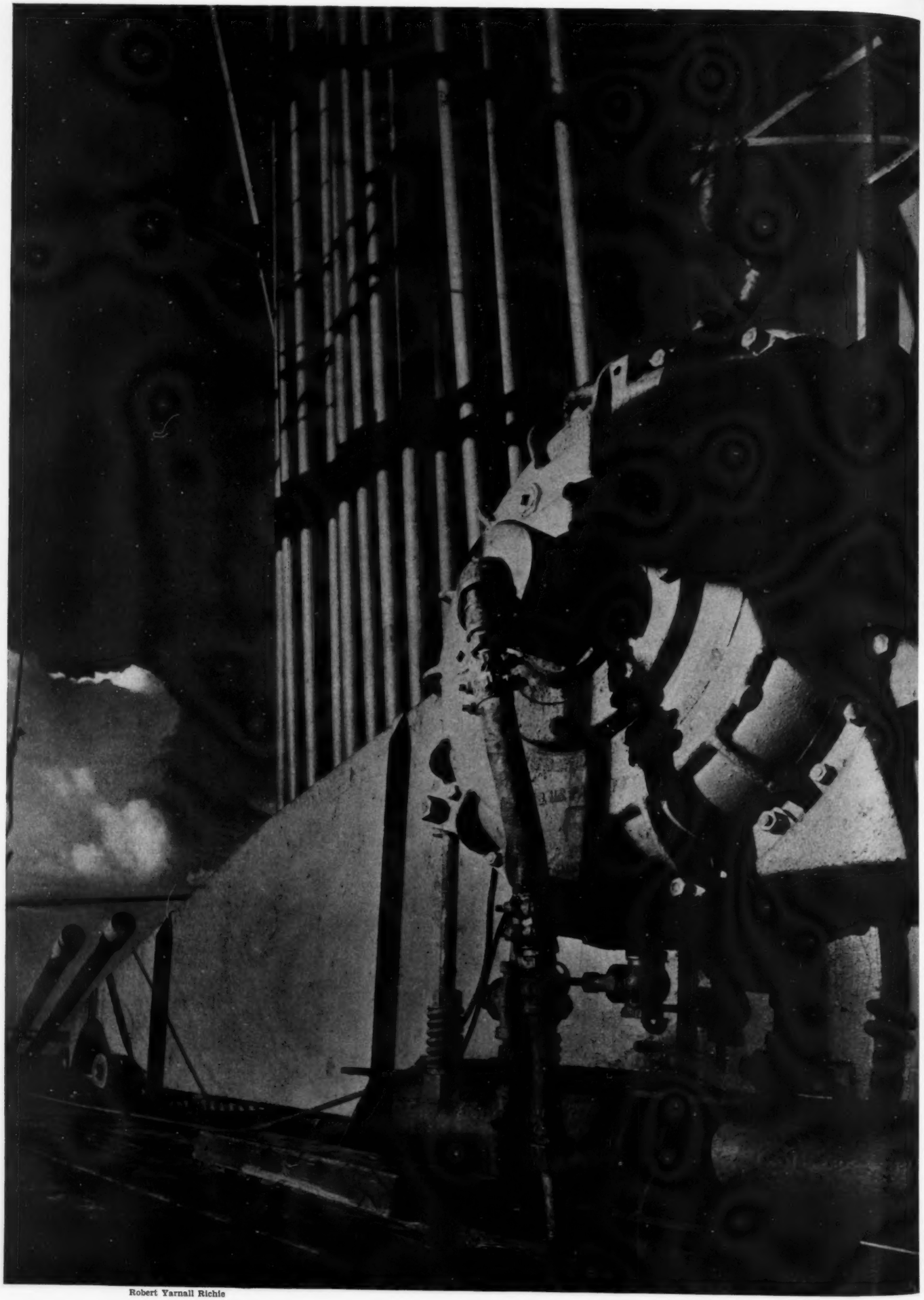
MANUSCRIPTS and photographs submitted to the editor are received only at the owner's risk. Prompt consideration will be given to them.

The Publisher does not necessarily endorse the views expressed by authors of signed articles. In the service of readers he will not hesitate to give publication to signed opinions in direct opposition to his own.

Advertising rates obtainable on request.

COPYRIGHT

COPYRIGHT, 1940, by Russell Palmer. Contents may not be reproduced without permission.



Robert Yarnall Richie

Modern Drilling Equipment in Eastern Venezuela

EDITORIAL

WAR'S TOLL OF OIL FACILITIES

WITHIN the past two months millions of dollars worth of petroleum properties have been destroyed in Europe. How great the loss may be it is, of course, impossible to tell. Censorship draws a veil over the precise details. The only reports purporting to give such information come from the attacking forces who naturally enough are interested in making the damage inflicted appear as impressive as possible. Their statements tell of vast destruction, of huge storage plants and tank farms going up in smoke and flame, of communication lines disrupted and manufacturing plants set ablaze.

If the raiders are disposed to overstate the results of their attacks the defenders are even more concerned to minimize their effects. Their communiques represent enemy air raids as being without military importance and enemy bombs as expending their force on schools, hospitals and here and there a few hapless civilians. Obviously neither belligerent is willing to acknowledge injuries that would lessen his ability to attack or to resist. Knowing the system of control that is applied to all news reports the non-belligerent discounts the statements of both sides and assumes that the truth lies somewhere between the conflicting claims.

With full allowance however, both for exaggeration and disparagement it probably is true that no other class of property has suffered so severely since the intensification of the conflict as has that devoted to the handling of petroleum products. In concentrating air attacks upon the destruction of oil depots and refineries and attempting to interrupt the movement of oil supplies the combatants are recognizing the vital part that petroleum plays in modern warfare, an importance emphasized especially by Germany's extensive employment of mechanized equipment.

British air raiders feel that oil supply is the Achilles heel of Germany and that by bombing oil stores and transport lines they are hastening a shortage of this essential material that is bound to make itself felt if their blockade holds. The Germans use their submarines to sink tankers and their planes to smash docks and terminals in the effort to cut the stream of oil that flows overseas to Great Britain.

The destruction that has taken place has been of two kinds. One comes from attacks by sea and especially from the air. The other consists in the wrecking of plants to keep them from falling into enemy hands. Some authentic information does seep through the lines of military control. These reports indicate that the persistent raids of British bombers, directed against storage depots, railway lines and manufacturing establishments and extending all the way from Norway to the interior of Germany have caused a great deal of damage to these objectives. German raids on Britain have been directed against harbor works and marine terminals and have put obstacles in the way of the prompt handling of supplies while perhaps not causing so great a loss of actual fuel.

When the tidal wave of German attack swept across Holland, Belgium and France, refineries and storage plants in the pathway of the invading forces were blown up on being abandoned and were left as huge heaps of twisted metal. The great refineries of Northern France, comprising the greater part of the refining capacity of the country, are reported to have met this fate. Not all the units of these plants were demolished but storage sections were drained and destroyed and vital parts of the refineries were put out of commission.

As a result of the widespread destruction that has taken place a vast work of replacement and new construction will confront the engineers and equipment manufacturers after the return of peace. While some of the refineries, storage plants and terminals that have been wrecked may not be rebuilt in the same form or in the same locations as before, the world's ever growing demand for petroleum products will necessitate their replacement there or elsewhere.

No doubt some of the obvious lessons of the war itself will be applied in carrying out this work. For example the past policy of France in developing a great system of refineries in exposed locations for processing imported crude instead of depending in

greater degree upon the importation of finished products may not be repeated. The vulnerability of this system was pointed out by practical oil men ten years ago when the plan for establishing national self-sufficiency in refining was adopted. Their advice was ignored then but events have sufficiently demonstrated its soundness.

Efficiency In Oil Recovery

On other pages of this issue Prof. L. C. Uren presents an interesting discussion of efficiency in production and shows the great strides that have been made in recent years. One of the thought provoking passages in his paper is his computation that in the fields already worked over in the United States there remain from 60,000,000,000 to over 100,000,000,000 bbl. of oil, or from three to five times the quantity actually produced, of which half or more may be recovered at some time in the future when slackening discoveries and rising prices make such action economically feasible. Here is a reserve not ordinarily included in estimates of potential output and one that is many times as great as the annually published estimate of known reserves. Here too is a challenge to future generations of oil men which undoubtedly will be accepted with improved implements to be developed in the future.

Complete recovery of sub-surface deposits remains unattainable, not so much because it is beyond human ingenuity as because it is economically impracticable. As to what proportion of the oil in a given field it is scientifically and commercially feasible to recover no exact answer can be given. We can measure the oil brought to the surface but we can only estimate the quantity left behind. Scientifically guided these estimates may possess a high degree of accuracy, but they still leave room for divergent views among experts. Differences in opinion appear to result mainly from varying calculations as to the original contents of the reservoirs in which the oil is contained, some geologists holding that these are overestimated in the usual system of measurement.

In a hearing before the T N E C a few months ago, Ralph Schilthuis of Humble Oil and Refining Co. presented a careful analysis of the efficiency of production methods employed in the states of Texas, New Mexico and Louisiana. He concludes that the percentage of recovery is higher than usually estimated in the past. On this subject Mr. Schilthuis brings out some interesting points, particularly in reference to the relation of connate water to estimated deposits. He says:

"The misconceptions of recovery efficiency were caused by (a) the fact that connate water occupies an appreciable portion of the pore spaces throughout the reservoir and less oil is present originally than formerly believed, (b) failure to appreciate that the gas dissolved in the oil under reservoir conditions occupies an appreciable volume and that the oil shrinks as the gas is released from solution during the process of recovery. The quantity of water found in the pore spaces even in the midst of the oil-bearing section of the reservoir may vary widely, depending largely on the permeability of the rock, and may fill as little as 10 percent of the pore volume of very permeable sands up to very high percentages for sands of low permeability. It is common to find half of the pore space filled by water and only half filled by oil. The water exists as a film adhering to and covering the pore surfaces of the rock, leaving the oil free to move within water-jacketed pore spaces.

"The shrinkage suffered by oil due to release of its dissolved gas during the course of the production operations has been determined in a number of cases by laboratory examination of actual samples of reservoir oil and gas. The amount of shrinkage depends upon the quantities of dissolved gases released and may vary from a few percent up to as high as 30 percent or more. The shrinkage averages between 15 and 20 percent for a large number of Texas, Louisiana, and New Mexico oils.

"The oil yields obtained from fields produced under wide open conditions which are depleted or nearly depleted in Texas, Louisiana and New Mexico commonly indicate recoveries ranging between 500 and 900 bbl. per acre-foot of productive oil section particularly from fairly permeable sandstone reservoirs which were subject in their later life to some water drive. An average yield of 700 bbl. per acre-foot considering 25 percent porosity and failing to account for connate water saturation and shrinkage, would lead one to conclude that only 36 percent recovery was obtained if it was believed that the pore volume was originally filled entirely with oil. If it were known that the connate water saturation actually happened to be 25 percent and the shrinkage 15 percent, the conclusion would be quite different, as the yield would really amount to 57 percent of the total oil originally in place. Considering further the fact that a quantity of oil equivalent to a minimum of 15 percent of the pore space is unrecoverable by any practical operation even under the most favorable circumstances, the efficiency of extraction of what may be termed the recoverable oil in place was approximately 70 percent."

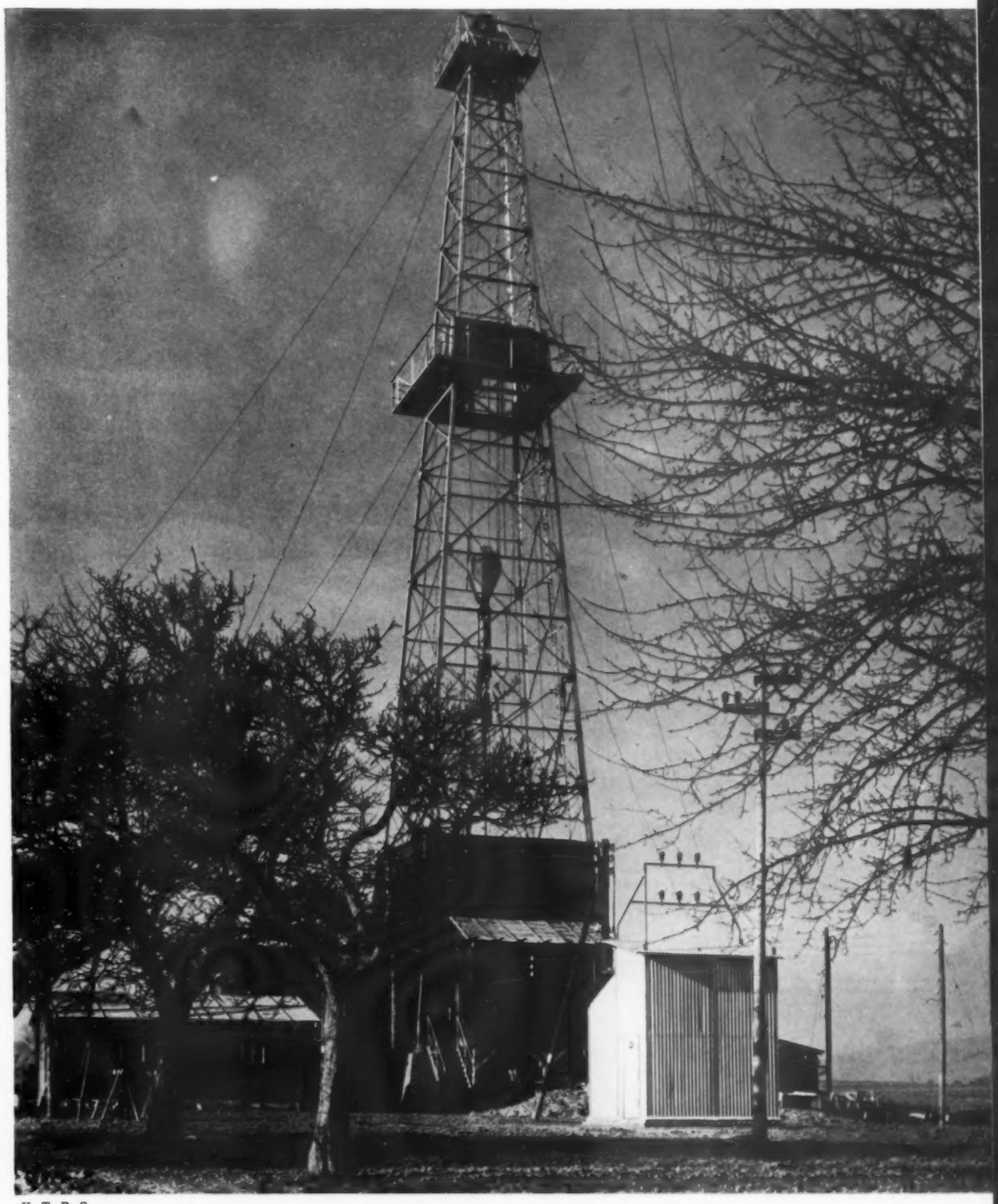
War Intensifies Oil Search in EUROPE

Desire of Governments to Discover or Expand Indigenous Supplies Leads to Encouragement and Expansion of Exploratory Activities—Initial Discoveries in Several Countries.

DISTURBANCES created by the war in Europe have interfered in some few instances with the work of exploration and drilling which was being carried on by individual groups and companies at its commencement. On the whole, however, the war has acted as an incentive to the search for oil. Governments, both neutral and belligerent, have maintained exploratory operations where these were being carried on under governmental direction and have afforded assistance and protection in instances where such work was being prosecuted by private companies.

Under the conditions prevailing no other course could be expected. The campaigns of the past ten months have given a compelling demonstration of the vital part played by petroleum in present day military operations. Never before has the importance of oil supply been so impressively enforced upon peoples and governments alike. As a consequence the value of an indigenous supply capable of aiding even to a small extent in meeting national requirements has taken on new importance.

Next to the United States the countries of Western Europe constitute the world's largest consuming group for petroleum products. Unlike the United States, however, these countries have produced only a negligible part of their annual needs. In all Europe the only nations that have been able to supply their necessities through their domestic output have been the Soviet Union, Roumania and former Poland. The only ones that have had an export surplus have been Roumania and to a decreasing extent the Soviet Union.



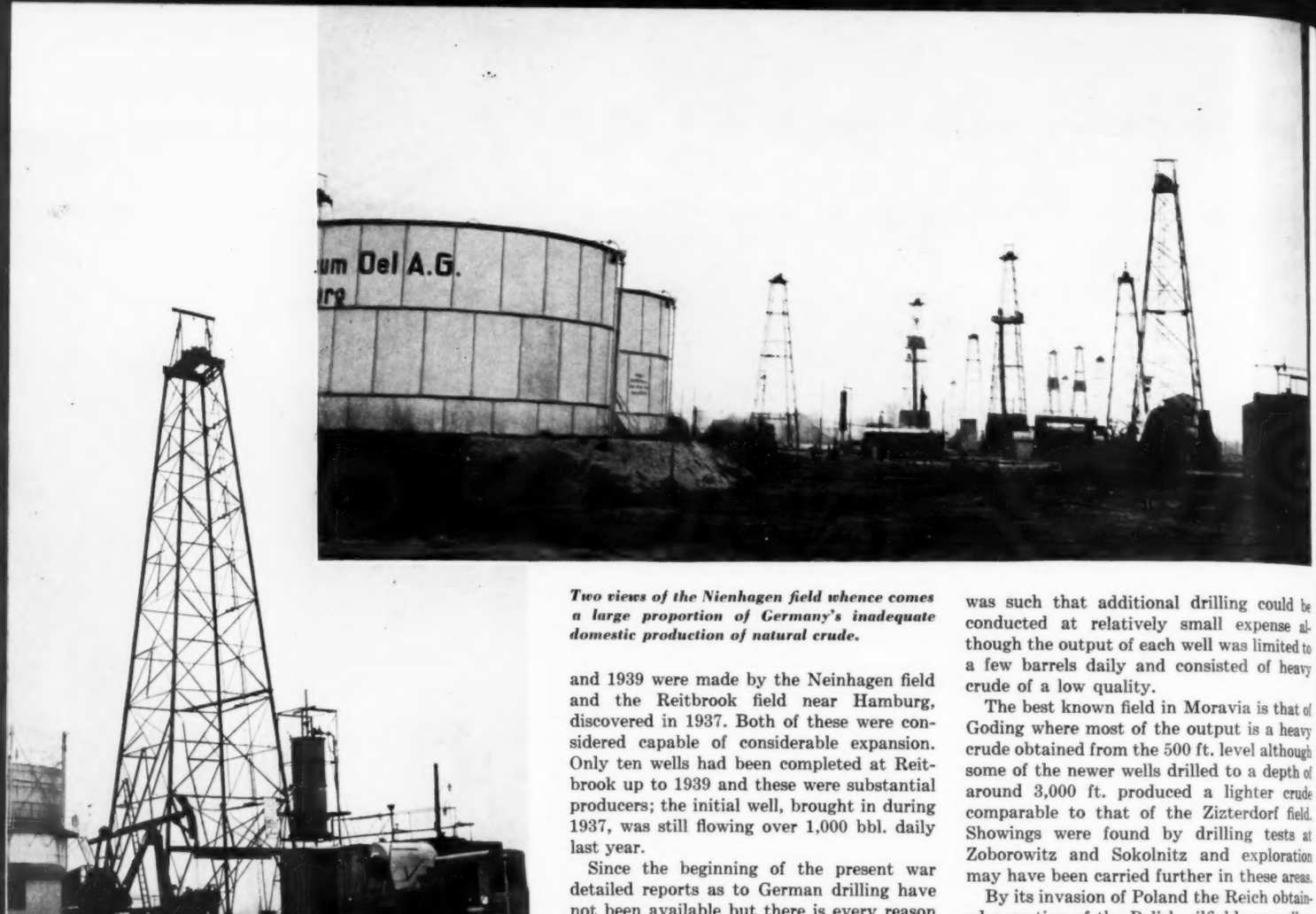
U. T. P. S.

A 5,000 ft. test being drilled a few years ago at Pechelbronn, France with a heavy American-made rotary.

GERMANY

Yearly peacetime requirements of petroleum products by Western Europe are in the neighborhood of 45,000,000 metric tons. Wartime requirements probably extend to 70,000,000 tons. Production in all Europe outside the Soviet Union is in the vicinity of 8,000,000 tons of which 80 percent is provided by Roumania. Other countries can provide less than five percent of their ordinary needs. Europe's chances of becoming self-sufficient in the matter of oil are slight indeed but this fact gives added importance to the development and exploitation by the various nations of such resources as they may possess. Efforts in this direction will continue to be pressed during the continuance of the war and will go forward with added vigor following its conclusion.

Of all the countries in Europe none has greater incentives to expand its domestic output of petroleum than Germany. It is a military nation and an industrial nation. Its consumption of petroleum products was increasing at a very rapid rate prior to the beginning of the present war and had more



Two views of the Nienhagen field whence comes a large proportion of Germany's inadequate domestic production of natural crude.

than doubled in the five years preceding. Moreover, Germany's geographical position is such that imports by sea, and even by land, might be shut off in the event of hostilities as happened in the first world war and again in the present conflict.

During the past seven years, since the commencement of the Nazi regime, an intensified effort has been made to develop the indigenous oil resources of Germany and this movement has had the encouragement and direct financial assistance of the government. This has resulted in increasing the output of German wells from 237,000 tons in 1932 to 647,000 in 1939 and thirteen new proven areas were discovered up to the middle of 1939. During the past three years drilling proceeded at the rate of between 800,000 and 900,000 ft. annually. During 1939 about one-third of this was in proven fields and the remainder was directed to the extension of these fields and the exploration of new areas.

The most important producing section of Germany is the Hanover area and the largest contributions to new production during 1938 and 1939 were made by the Neinhagen field and the Reitbrook field near Hamburg, discovered in 1937. Both of these were considered capable of considerable expansion. Only ten wells had been completed at Reitbrook up to 1939 and these were substantial producers; the initial well, brought in during 1937, was still flowing over 1,000 bbl. daily last year.

Since the beginning of the present war detailed reports as to German drilling have not been available but there is every reason to believe that activities in this direction have been stepped up rather than otherwise. Oil men familiar with conditions at the outbreak of the war express the opinion that the footage drilled during 1940 will be double that of 1938 and 1939 and that production in the Altreich from existing fields will be substantially increased.

At the same time Germany has been adding to its oil resources by territorial expansion. Acquisition of Ostmark (Austria) brought with it a production of about 65,000 tons annually which has since been increased to over 100,000 tons. Much of this increase has come from the Zisterdorf field near Vienna. The Gaiselberg field which had an average production of 400 bbl. daily from the four wells first drilled was expected to provide a substantial output as soon as adequate transportation facilities could be provided which may have been done before this time. Another field that attracted much interest early last year was St. Ulrich where a test well yielded nearly 500 bbl. daily. Further drilling was projected in this area while another section marked for exploration was in the Styria district in the vicinity of Gratz.

Czechoslovakia, which was brought within the German orbit early in 1939, had a production of about 20,000 tons annually. Several small fields existed in Slovakia of which the most important was that at Gbely owned by the government, Production in these areas was from shallow wells under 1,000 ft. in depth. The nature of these fields was such that additional drilling could be conducted at relatively small expense although the output of each well was limited to a few barrels daily and consisted of heavy crude of a low quality.

The best known field in Moravia is that of Goding where most of the output is a heavy crude obtained from the 500 ft. level although some of the newer wells drilled to a depth of around 3,000 ft. produced a lighter crude comparable to that of the Zizterdorf field. Showings were found by drilling tests at Zoborowitz and Sokolnitz and exploration may have been carried further in these areas.

By its invasion of Poland the Reich obtained a portion of the Polish oilfields as well as several refineries and connecting pipelines. In the partitioning of Poland, Germany received the western oilfields with an output of about 1,000,000 bbl. (143,000 tons) per year, less than 30 percent of the country's annual production of some 3,800,000 bbl. In the opinion of geologists familiar with the area, however, it is held that some of the western fields are capable of considerable expansion through the application of modern methods of production. While no information has been given out as to the extension of drilling operations since the conquest it is known that existing wells in Poland as well as those in former Austria and Czechoslovakia are being pumped hard in an effort to obtain maximum production during the war.

Germany's production from the original area of the Reich and the conquered territories occupied since early 1939, therefore reaches roundly 875,000 tons at the rate of output in effect during the past year. How much this may have been increased by efforts already referred to is wholly conjectural but it is practically certain that production during 1940 in these various areas will exceed 1,000,000 tons and that new drilling will at least double the 1938-39 average.

ROUMANIA

No oil district has been more in the public news in the past year than Roumania. As the one country in Europe with an important export surplus and with access (at the begin-

ning of the present war at least) to all the contending countries the diplomatic and commercial struggle for its available surplus has been as much a part of the general conflict as have the purely military moves. As a result of rival bidding Constantza prices more than doubled during the first months of the war.

Such a condition, had it existed without other complications, might have been expected to act as a stimulus to drilling activity. On the other hand the political uncertainty of Roumania's position and the possibility of sudden invasion made investment in such ventures unattractive to the established producing companies who were the only ones in a position to carry on work of this character. Consequently these companies have limited their activities to the completion of drilling projects under way before the outbreak of war or to such new exploration as was required by the terms of their agreements with the government.

German interests have been trying to get control of certain existing companies and to obtain exploration permits covering new areas. So far as is known, however, only one company of any importance has passed under German control and in the case of new areas a considerable amount of preliminary work in the way of surveys and tests is required before drilling, for commercial production can be undertaken. The situation is, therefore, that the footage drilled in Roumania during the current year probably will be less than in 1939 and certainly no greater.

One reason given for the decline in Roumanian production during recent years has been the onerous nature of the mining law which discouraged exploration. A revision of its regulations has been promised for the past several years but through one delay after another was not put into effect. Drilling, therefore, has been confined to the maintenance of production in existing fields and little wildcatting in new areas has been attempted.

In 1939 the number of wells drilled was 150 for a total of 850,000 ft., as compared with 960,000 ft. in 1938. Production in 1939 was 6,228,000 tons as compared with 6,603,000 tons in 1938 and 7,153,000 tons in 1937. During the first six months of 1940 drilling operations have been somewhat less than in 1939. This has been due to unsettled conditions, to unfavorable weather in the early part of the year and to the difficulty of securing delivery of equipment and obtaining exchange in payment for it.

If Roumania retains its independence and escapes involvement in the war it is probable that the return of stable conditions will be followed by a revision of existing regulations and an extension of exploration to new areas. For the present such a development is not to be expected.

ITALY

While Italy's oil industry is practically as old as that of the United States, production has been confined to a few small fields and the maximum output, reached in 1932 was only a little over 28,000 tons (205,000 bbl.). In the past few years this has declined to about 14,000 tons. This quantity is relatively insignificant compared to the country's requirements of around 4,000,000 tons annually and the situation has led the government to establish a semi-public company and to lend financial support to plans for a thorough going exploration of the Italian terrain in the effort to discover additional oil supplies.

Several of these programs have been put forward in the past ten years, but for various reasons, the most important being perhaps inadequate appropriations, they have not resulted in a sufficiently complete examination to prove the presence or absence of oil in commercial quantities. The surveys made have defined a petroliferous fold at Fontevivo from which some thousands of tons of oil have been recovered, have opened important natural gas deposits in the Emilia region of the Apennine foothills, and, finally, have convinced geologists that deeper drilling is necessary to reach oil bearing horizons that may exist in certain areas such as the Po valley. Now a new and more exhaustive campaign of exploration has been mapped out for the next five years.

At a recent meeting of the Italian council of ministers the semi-state controlled Azienda Generale Italiana Petroli (A.G.I.P.) was granted a subsidy of 125,000,000 lire to help finance a five-year drilling program that will end June 30, 1945. This fund is ear-marked for wildcatting on the Italian peninsula and in Sicily. Later the council voted a subsidy of 25,000,000 lire to the Azienda Nazionale Idrogenazione Petroli (A.N.I.P.) for similar explorations, principally in Albania. Both these concerns have lately enlarged their

Primitive winding gear for bailing and cleaning Roumanian wells.

© British Combine

capital by new stock issues and an amalgamation of the two is in progress.

The object of the plan is to obtain definite information on the possible existence of petroleum in the Italian subsoil. It is specifically designed to test the theory of the geologists and the geophysicists that beneath the continuous mantle of Neocene and Pleistocene deposits that cover the Po basin and the whole Adriatic slope of the Apennines there exists a geosyncline which contains structures that may yield oil in commercial quantities, though perhaps at considerable depths. The Apennine region itself now appears to be definitely out of the picture. Traces of oil and other hydrocarbons are found at numerous places in these mountains, but according to the geologists the tectonics of the region are more complex and confused than are to be found in any similar regions of the earth, which reduces the prospect of commercial production virtually to zero.

The localities selected for wildcatting have been indicated by government officials. One set of wells is to be drilled, the Azienda Generale Italiana Petroli and the other group by the A. N. I. P. The announced intention is to use only Italian technical personnel.

While undertaking this large scale exploration of its homeland Italy is not neglecting efforts to expand the oil production of Albania now the principal source of domestic supply. In the past five years extension of the Albanian fields has increased yearly production from 6,000 tons in 1935 to over 200,000 tons in 1939. Operations here are under the direction of the Azienda Italiana Petroli d'Albania (A. I. P. A.) and in the Devoli fields 380 wells with average depths of between 2,000 and 2,500 ft. had been drilled up to 1939.

During the latter part of last year an enlarged campaign of exploration was initiated. American drillers and American equipment were employed for carrying the exploration to greater depths. To what extent this project has advanced or what results have been obtained has not been reported.

HUNGARY

One central European country in which production has increased rapidly during the past two years is Hungary. This has come about mainly through development of the Lispe area under a concession held by the Hungarian American Oil Industry Co. This includes several fields of which the principal one is Buda. Production was first obtained at the end of 1937. By midsummer 1939 the number of wells had reached 19 and daily output was about 2,000 bbl.

Since that time drilling in the proven area has continued and the number of completed wells has risen to 40 with a yield of about 5,000 bbl. daily. With additional production from the wells now under way it is expected that before the end of 1940 the daily output will be raised another thousand barrels or sufficient to meet the full domestic requirements of the country which are something over 2,000,000 bbl. yearly. To facilitate the distribution of the crude a pipeline of 3,500 bbl. daily capacity was projected from the Lispe area to Budapest to supply refineries adjacent to the city and from there by barge up the Danube river to other refineries. Construction work is now under way.

Exploratory work under the direction of the Hungarian government has resulted in small production at Buk Kszek, but this is of minor importance compared with the Lispe area. It was reported early in the present year that prospecting around Lake Balaton in the Province of Zola had given favorable indications and that it was believed that a field might be developed on the northern side of the lake but no recent news of further operations in that section has been received.

Producing wells in Hungary vary in depth from a few hundred feet to over 8,000 ft., but the average is about 5,000 ft. The deepest test in the country was a wildcat drilled at Magyar St. Miklos which reached a depth of over 8,500 ft.

In Yugoslavia a group of German industrialists are reported to have obtained a drilling concession covering an area in the northern part of the country nearly opposite the development of the Hungarian American Company in southern Hungary. It is believed that similar structural conditions exist in this district. Last year Socony-Vacuum filed application for an exploration concession. Developments in Yugoslavia are still in a preliminary stage however.

During the latter part of 1939 the Bulgarian government conducted some geological research to determine whether the prospects of finding oil deposits were sufficiently encouraging to justify drilling. A party of mining engineers, acting for the government was authorized to make a special investigation of conditions in the Varna and Provadia districts in northeastern Bulgaria. No report on either of these investigations has been made thus far.

In Greece two American rotary drilling rigs have been engaged in exploring oil possibilities. One of these is operated by Western Greece Oil and Asphalt Co. which holds a concession in Epirus in the northwest part of the country. The other was brought in by George Helis, an American of Greek extraction who is a well known operator in Louisiana. Mr. Helis holds a concession covering exploration right to all Greece except the area previously granted to Western Greece Oil and Asphalt. In 1939 he shipped complete equipment for deep drilling with a crew of American operatives to start the drilling of a first test well. Several months ago it was reported that showings of oil had been encountered at the depth of approximately 3,000 ft. No later reports have been received. Western Greece Oil and Asphalt Co., which is financed by English capital is primarily concerned with the exploitation of asphaltic oil sands in western Epirus and its first undertaking was to drive a tunnel into one of the hills along the Molitza Valley in an effort to determine the extent of these deposits. Thus far the question whether Greece contains oil deposits of commercial value remains unanswered.

While Pechelbron has remained the one dependable oil producing area of France with a yearly output around 500,000 bbl. prominent French geologists, notably M. Leon Bertrand, from time to time have urged the systematic exploration of the districts in the southern part of the country in the foothills of the Pyrenees as affording favorable prospects for the discovery of other deposits of considerable importance. As a result of these recommendations a certain amount of desultory drilling was done. In 1924 a well put down on an anticline south of Gabian, in the southeastern corner of the country, produced an intermittent flow of over 100 bbl. daily. This led to the drilling of between fifty and sixty additional wells and a production that reached between 40,000 and 50,000 bbl. in 1926.

FRANCE

Gabian proved to be a localized pool, not a field, and its output gradually declined to a few barrels daily. It demonstrated, however, the existence of an ancient oil source and encouraged hopes of finding a more prolific area further westward. In 1935 the French government set aside certain districts in Herault, Haute Savoie and Puy-de-Dome for exploration by the Office Nacional de Combustibles Liquides and provided a substantial appropriation for the work. Two heavy type rotary rigs, capable of reaching greater depths than had hitherto been attained, were purchased and early in 1939 a wildcat was spudded in near St. Marcet in Herault. This well encountered a heavy flow of gas at a depth of 5,000 ft. and the conclusion was reached that it had been drilled at the top of the structure. A second well was started at Pinat, near the centre of the area marked out for exploration. In May last this well was brought in from about 6,000 ft.

According to a semi-official statement the flow "through an 8 mm orifice at a pressure of 95 kg. was found to be several tons per hour." While this quantity of "several tons" is somewhat indefinite the discovery has raise strong expectations that important production will result from further tests. French officials are particularly pleased with the high quality of the oil which they describe as closely resembling Pennsylvania crude, with "22 percent of pure gasoline, a lubricating content equal to that of the best Pennsylvania oils and four percent of paraffine."

The discovery at Pinat is regarded as the most important development in recent French oil history. It will be followed up by additional drilling as rapidly as circumstances will permit and may lead to a substantial addition to the country's petroleum resources.

An enlarged drilling campaign was planned for the current year by Pechelbronn S. A. which had received permits to drill at Sundhouse and in Haute Savoie. For this work a high powered rotary and another of medium size were added to the equipment which the company previously had in operation. Intervention of the war has cut off recent reports and may have led to a suspension of the program.

A heavy rotary operated by A. G. I. P. in Italy which drilled to 2,000 meters.

PORTUGAL

Under a concession granted last year giving to the Anglo-Portuguese Oil Co., Ltd., the right to explore for oil in all parts of the country a test well is drilling at Torres Vedras, 30 miles north of Lisbon. In April this well encountered very good showings of oil at a little less than 2,000 ft. A sampling of returns from the well showed an asphaltic type oil (gravity 0.928) with a high sulphur content.

While these showings are regarded as encouraging drilling is being carried on in the hope of finding oil of higher quality at lower depths.

UNITED KINGDOM

Before the outbreak of war the campaign of exploration inaugurated in Great Britain in 1935 had resulted in the bringing in of producing wells. Since that time work has continued and more successful completions have been made. In deference to the wishes of the government details of drilling operations are not being published for the present.

DENMARK

Following an extensive geophysical survey of Danish areas the Danish American Exploration Company, subsidiary of Gulf Oil Corporation, has been engaged in exploratory drilling during the past several months. Since the German invasion of Denmark and the consequent difficulties of communication and transportation this work has been suspended temporarily.

SOVIET UNION

According to claims of Soviet officials the crude oil reserves of the U. S. S. R. are greater than those of any other country in the world. While Russian claims as to known reserves are sometimes scouted there are many practical oil men outside that country who agree that Soviet oil resources probably surpass those of any other nation. It is stated in Soviet reports that during the past five years more than 40 fields have been discovered and brought into production in the Ural-Volga, Middle Asia and Far East regions together with new areas developed in the Baku and Grozny districts.

The problem of the Soviets is not so much that of finding oil as of producing, transporting and processing it in quantities sufficient to keep pace with the growing domestic demand arising from the progressive industrialization of the country. In the effort to accomplish this many shortcomings and delays have been encountered as revealed by Soviet reports and comparison of actual performance with advance plans.

Slowness in drilling which required inordinate lengths of time to complete wells of only moderate depth under easy drilling conditions is one of the most frequent complaints encountered in these reports. Those in charge of field operations report that they are hampered by the poor quality of tools supplied, by delays in providing supplies and equipment and by the lack of decent dwelling accommodations in the isolated sections where much of the exploratory work is carried on. Apparently inefficiency is not confined to any one branch of the service.

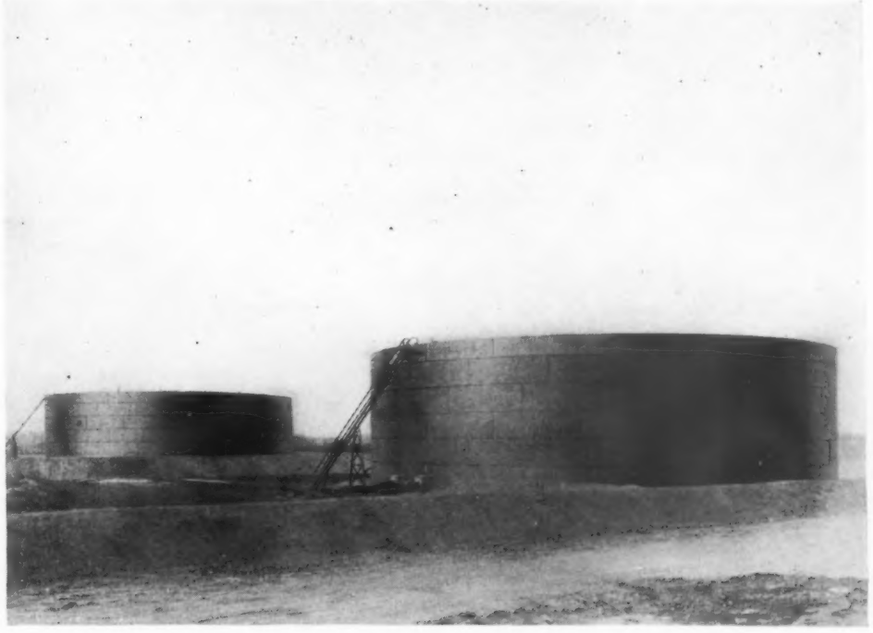
A recent report in "Industria", Soviet trade journal, asserts that drilling is the weakest feature of Soviet oil operation and states that exploratory drilling in the Ural-Volga region in 1939 was 60 percent of the amount called for by the five year plan while in 1938 it was only 49 percent. Exploitation drilling was 63 percent of plan in 1938 and only 56 percent in 1939.

Field	Percent of Plan
Baku	61
Grozny	59
Maikop	60
Daghestan	48
Georgia	117
Emba	97
Turcman	51
Ferghana	61
Sakhalin	83

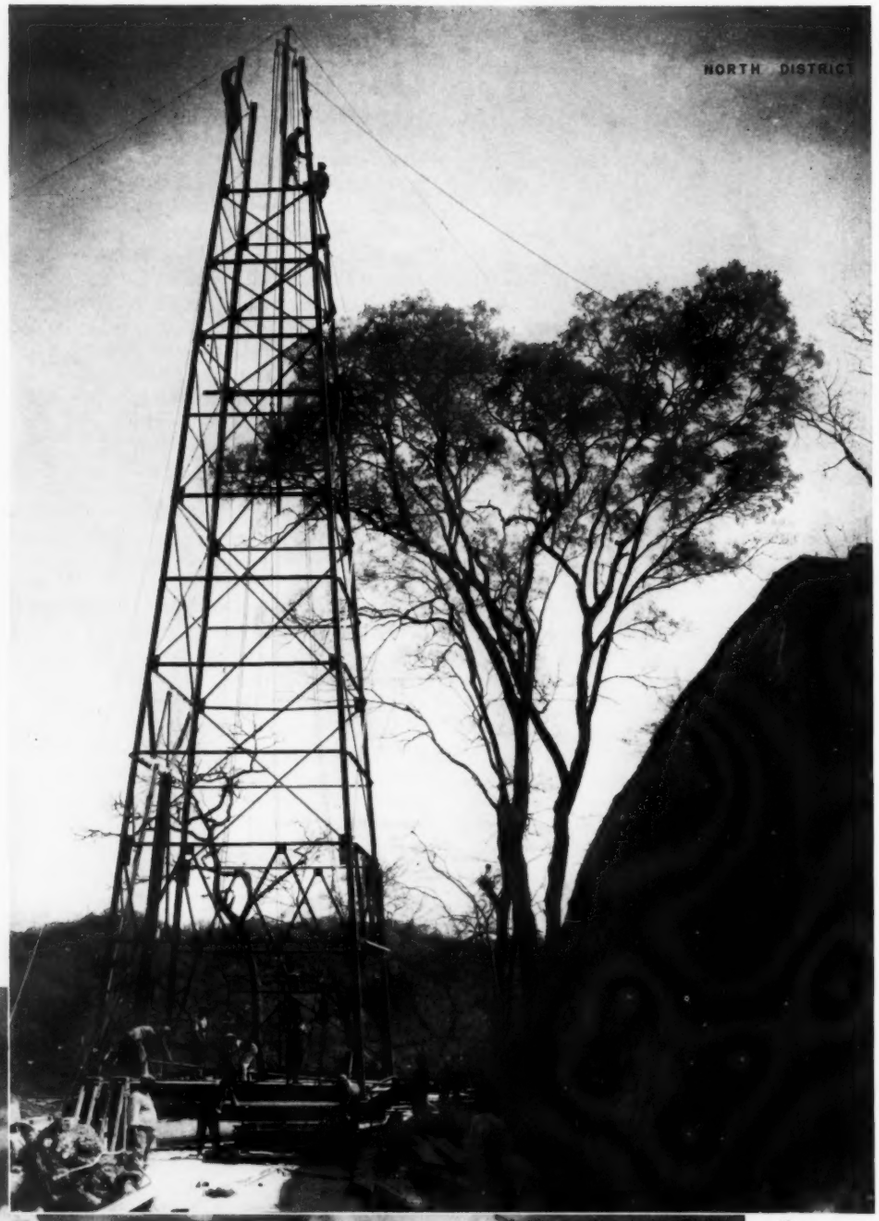
It is stated that while records at Baku indicate that in the productive area of that district an average of 225 days is required for erection of the derrick, drilling and completion of the well for production, this conclusion is erroneous as another twelve months is often required after drilling before the well is ready for production. Completed wells are abandoned because of being placed in wrong locations or being improperly drilled.

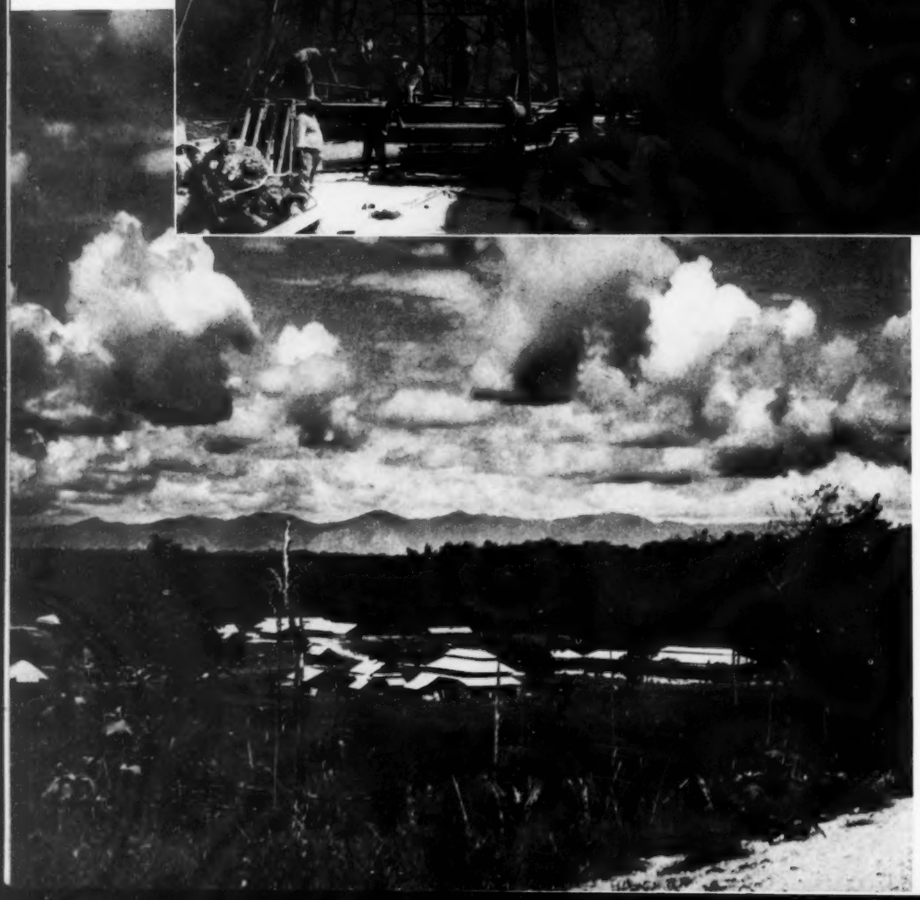
The Soviet plan calls for a production of 54,000,000 tons, including natural gas, in 1940. The drilling program provides for 2,135 wells, but unless past records for drilling are improved upon it appears improbable that this record can be attained.

Two of the largest crude storage tanks in the world, 168 ft. in diameter, with 182,000 bbl. capacity each, they were erected by Graver Tank and Manufacturing Co. at East Chicago.



ACTIVE DEVELOPMENT IN SOUTH AM





Above, setting up a rig in northern Argentina, a country that expects to be independent of oil imports soon: Left, Socony-Vacuum's Aguas Claras camp in the Magdalena Valley of Colombia.

Wildcatting in Venezuela and Argentina — Huge Areas Under Exploration in Ecuador—Success Crowns Brazilian Government Drilling Campaign—Leasing Activity Declines in Magdalena Valley of Colombia.

IN VIEW of the tremendous reserves of oil available in South America and the long term plans that have been set up for the development of these reserves, it may be assumed that the present period of decreased activity in the fields below the Rio Grande will be of a temporary nature. Dislocation of world commerce and uncertainty as to the immediate future as a result of chaotic conditions in Europe and the Near and Far East have played their part in decreasing the tempo of development; almost equally important is the failure of many of the South American governments to have achieved as yet a stabilized petroleum policy.

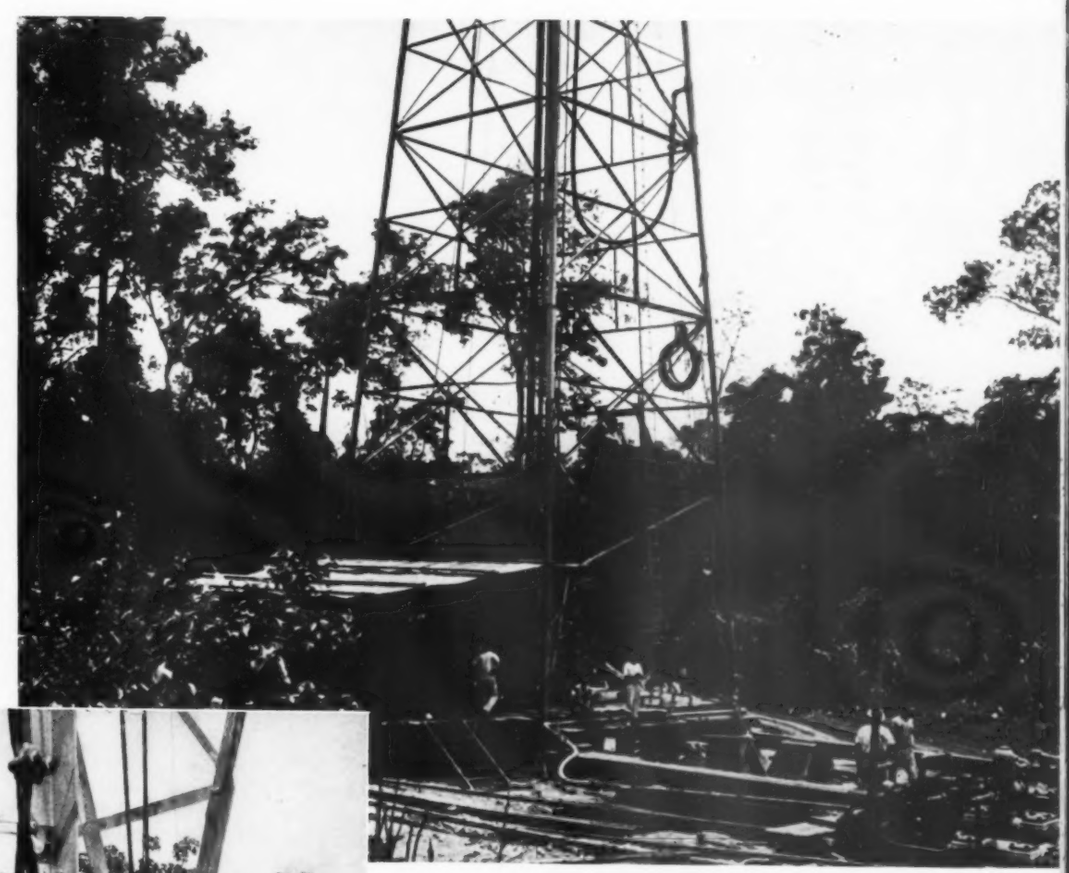
In Bolivia, confiscation of foreign owned oil properties is demonstrating again that abrupt transfer of oilfield operation from a private company to a state, complicated by political considerations and without adequate engineering ability available, results in bringing operations almost to a standstill. At the very least any rational exploitation program will be retarded several years.

Before proceeding with the discussion of present activity elsewhere in South America, it would be well to fix in mind the relative importance of the various oil producing countries of Latin America in relation to each other and to the world oil industry. Latin America including Venezuela, Mexico, Colombia, Trinidad, Argentina, Peru, Ecuador, and Bolivia produce 16.5 percent of the world's oil. Venezuela is far and away the most important, being responsible for 65.2 percent of South American production and supplying 10.7 percent of the world production. Even with its decreased production, Mexico comes second with 12.4 percent of all South American production and two percent of the world's production. Colombia is third most important producing country in South America with 6.6 percent of the total South American production. Trinidad and Argentina are almost equal in importance, the former having 5.7

AMERICA DESPITE UNCERTAIN OUTLOOK

percent and the latter having 5.6 percent of South American production. Peru has 3.8 percent, Ecuador but 0.6 percent and Bolivia less than 1/10 of one percent. Potentially, however, there is reason to believe that South America will be even more important in relation to the rest of the world in the near future; the only area at present showing equal or greater potentialities is perhaps the Near East.

Argentina, where the government is playing a constantly more important part in the petroleum industry appears to be one country where state participation is working with a measure of success. Here, of course, the government has injected itself gradually and in a legal manner, avoiding the abrupt changes that caused serious dislocation in Mexico and Bolivia. Private operations are by no means entirely discontinued in Argentina. The Texas Company, in fact plans to drill three wildcats there in September of 1940. Two of these will be in the north, one in the province of Salta, one in the province of Jujuy; the third will be in the south, in the province of Santa Cruz. The exact locations of these operations have not yet been revealed, but



EASTERN VENEZUELA

BRAZIL

equipment is already on the ground and locations will be prepared soon.

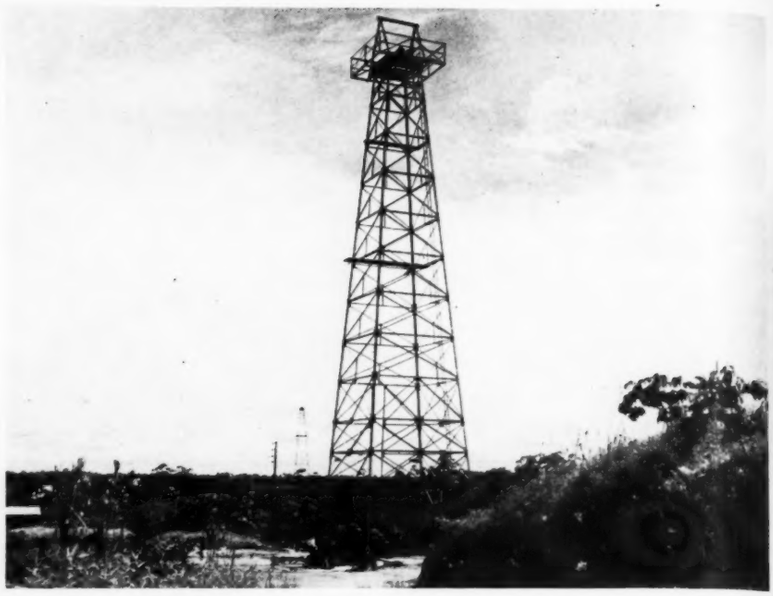
Yacimientos Petroliferos Fiscales the government sponsored operating agency has been busy during the past year developing its recent discovery near Tupungato in the province of Mendoza. The field has not been defined on any side as yet and it is believed to be extensive. Present wells indicate as much as 800 ft. of sand at 6,000 ft. and production is of the order of 1,000 bbl. per day. Three rigs are in operation at present.

Venezuela, as pointed out in a special issue of WORLD PETROLEUM (December 1939) devoted to the oil industry of that country, achieved its present preeminent position in South American oil production by affording a long period of stable oil legislation favorable to exploitation by foreign capital. During this time the large aggregations of capital and technical skill necessary to sound development, were enabled to block out development plans and carry them into effect in a manner calculated to bring the greatest return to the government and on the capital invested. In other respects, however, political conditions were unsatisfactory and during the past few years social reforms have swept the country imposing heavier obligations on the oil com-

panies operating in Venezuela. While no extreme measures are anticipated, the petroleum policy of the nation may be said to be in a period of transition which may be responsible in some measure for hesitation on the part of the most important companies in proceeding with development plans on the scale that would be necessary for continued expansion of the industry at the rate it has enjoyed in the past. Moreover, as the greatest part of Venezuelan crude ultimately reaches Europe, the uncertainty in that quarter has been reflected in Venezuela more than elsewhere in South America.

In western Venezuela the principal development work is being carried on in the Bachaquero field, the location of which has been known for some time although the field has not been drilled up until now. This field lies some 28 km. south of Laguanillas on the shore of Lake Maracaibo and about 25 km. above Mene Grande field. One well is being drilled off shore by Lago Petroleum Co. (SONJ). Venezuela Oil Concessions (Shell) has completed four wells in the present campaign and is presently engaged in drilling the fifth. Mene Grande Oil Co. (Gulf) is running two strings in Bachaquero and has completed Lagunita Nos. 9, 19, 21, 30, and 35. The road into the field was finished late in 1939, access to the field being by water before that. No oil is being shipped from Bachaquero at present nor will any be shipped for the remainder of the year as completed wells are being closed in for the present by agreement, sufficient oil for market requirements being available from other fields in the Bolivar Coastal district.

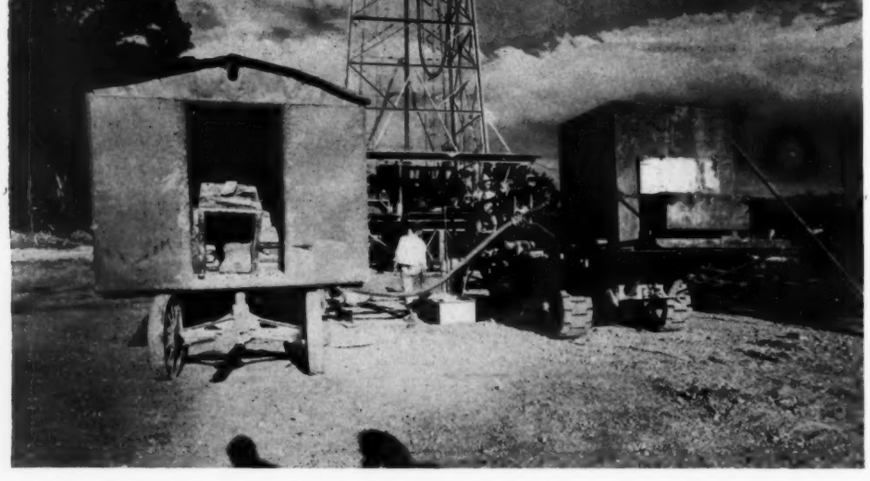
Active interest centers in eastern Venezuela where the M. G. O. C.'s Oficina field is now shipping about 40,000 bbl. per day through the 100-mile, 16-in. pipeline to Guanta (Pto. La Cruz). The Oficina field is defined on the north and northeast only and present operations are designed to define the field on the west, four strings being run in the step-out operations on this side of the field. There are 13 strings in operation in the general Oficina area. On the edge of the present field one well is drilling 7½ km. SW of Oficina No. 1 at 5,400 ft. on the 10th of June. Another extension well is being drilled 5½ km. SE of Oficina No. 1. Distillate produced from the San Joaquin field, drilled by S. O. V. is being run into the M. G. O. C. pipeline through a short lateral line originally constructed to supply gas to the San Joaquin drilling operations.



A producing well on the La Cira structure of El Centro operated by the Tropical Oil Co. in the Magdalena Valley of Colombia.

East of the pipeline M. G. O. C. is drilling Santa Rosa No. 2 eight kilometers SW of Santa Rosa No. 1, now at 2,500 ft. It is thought that this well is on the San Joaquin trend although it may produce from a different sand; and it is anticipated that it may go to about 7,000 ft. This test is being watched with great interest as it may indicate extension of the producing trend from San Joaquin as much as 25 km. northeast. In this area between San Joaquin and the M. G. O. C. Santa Rosa No. 2 test, Socony-Vacuum holds acreage on which they have already drilled one well, Guario No. 1 to 8,275 ft. Tests revealed oil shows in two sands. Socony-Vacuum is now engaged in drilling Guario No. 2 just south of the No. 1 and by mid-June the bit had reached 4,753 ft.

Robert Yarnall Richie



Cementing a well in the Jusepin field in Eastern Venezuela.

Just north of the San Joaquin-Santa Rosa No. 2 trend is the El Roble field only 14 km. from the M. G. O. C. pipeline where El Roble Nos. 1 and 2 were completed some time ago as producers of light crude from almost 10,000 ft. This field is operated by Standard of Venezuela for the Pantepec Petroleum Company.

South of these developments The Texas Company is drilling Rincon Largo on the southeast edge of the Santa Ana field, at 8,460 ft. on June 15th. This well is located some 30 km. southwest of El Roble and 51 km. northwest of Oficina. The Texas Company is also drilling Caritos No. 2 on the edge of the Delta Amacuro on the east side of the Orinico at a point where the river bends sharply to the west. This test was spudded in the middle of June a short distance northeast of Caritos No. 1 on the other side of the river. No. 1 was completed as a producer some time ago.

In the central part of Venezuela, Standard of Venezuela is drilling Gorrin No. 1 for Mene Grande Oil Co. on a location almost directly south of Caracas. The location is 63 km. southeast of the city of Calabozo. Late in June the drill had reached 1,200 ft. It is probable that a second well will be drilled in this area even if Gorrin No. 1 produces no positive results. It is interesting to note that about 98 km. east of this test, geologists connected with the Ministry of Fomento, drilling presumably for water wells, found oil shows in comparatively shallow sands.

The test being drilled by Caracas Petroleum Company 115 km. southeast of Calabozo known as El Machete No. 1 found small oil shows but insufficient for commercial production. The company has no immediate plans for further drilling in this area. The Texas Company, however, will drill a well on a location some distance north of El Machete for the joint account of Caracas Petroleum Company and The Texas Company.

Consolidated Oil Corp. is preparing to spud in a wildcat in central or eastern Venez-

Well completion at Petrolea on the Barco Concession in Colombia.

uela this fall and is now assembling equipment for this purpose. Exact location is not yet known.

In Colombia the government has achieved a more settled petroleum policy than in many of the other South American countries. Intense leasing activity and numerous applications for concessions on national lands prevailed until recently. Now, however, there is apparent some slackening in leasing activity. Drilling according to a regular program is proceeding on the La Cira structure of the great El Centro field of the Tropical Oil Company (through the Imperial Oil Company, Ltd. affiliated with Jersey Standard). The Infantas structure of this field is drilled up and except for workovers there is no further drilling there. Also on the Barco concession of the Colombian Petroleum Company and the South American Gulf Oil (both jointly held by The Texas Company and Socony-Vacuum) a regular program of drilling is progressing. In the Barco and El Centro fields there have been about 150 completions during 1939.

Wildcat drilling in Colombia is being carried on in the middle Magdalena Valley by the Shell Company de Colombia at a point 32 km. east and a little south of Pto. Berrio on the Shell concession that adjoins the De Mares on the northeast and the concession of Compania Nacional del Carare on the south. This operation is being carried on an anticline that extends into the Del Carare concession and is just southeast of the previous dry hole drilled by Shell on their concession. If results are favorable it may be anticipated that Del Carare will drill on the same anticline. Shell has already drilled Monteoscuro Nos. 1 and 2 and Baull No. 1, none of which obtained commercial production. Nacional del Carare has completed two dry holes and is presently engaged in drilling a third wildcat.

Socony-Vacuum Oil Company de Colombia has recently abandoned its Narino No. 3 at 10,740 ft., having obtained some oil shows but not sufficient to indicate commercial production. It will be remembered that Socony-Vacuum drilled Nariño No. 1 to 6,500 ft. and abandoned it; Peralonzo No. 1 ran into a fishing job below 9,000 ft. and had to be abandoned; and now with the failure of Narino No. 3 it is unlikely that the company will drill any further deep tests in the central part of the Aguas Claras concession for the present at least. However, one rig is being kept in operation in the Las Monas section of the concession where one well is now pumping 18 bbl. per day. This section in the south eastern part of the concession near the La Salinas fault comprises very steeply dipping beds with numerous faults making the outlook uncertain but the wells will not be as deep as the tests drilled in the central part of the concession and consequently less costly. The present drilling operation in this area had reached 3,750 ft. by the middle of June.

While not yet drilling The Texas Co. has on file with the government requests for drilling permits covering private leases in the Chaparral area of the Upper Magdalena Valley.

The Brazilian Government is proceeding cautiously with a drilling program that appears to be yielding good results. While the point might be raised that development of domestic production in Brazil would have proceeded more rapidly had private capital from abroad been permitted to engage in exploration, still results at present seem to justify the fairly stable program defined by the government. In Brazil no shock to an existing oil producing industry was involved, as production was negligible prior to the government drilling campaign.

The National Council in charge of all oil activities in Brazil, is not prepared at this time to release an authoritative statement on the results obtained by the present drilling campaign. Rumors persist, however, to the effect that at least two wells have been completed with an initial production in excess of 200 bbl. per day, which if true would be of major importance to the Brazilian national economy. If results are as favorable as rumor indicates there is no doubt that the national council will expand and intensify its drilling program.

In Peru the government has one wildcat drilling in the north and another near the Chile-Bolivia-Peru border. The most interesting development in Peru, however, has been the Aguas Calientes concession of the Ganzo Azul where a substantial producer was brought in last year. However, until some economical means of shipping the oil out of this section of Eastern Peru has been devised the drilling program is being held up. The wells already drilled indicate the presence of a sizeable reservoir but the difficulty lies in transporting the oil to market. The Andes make shipment of the oil to the west coast impractical; eastward Aguas Calientes oil would have to travel almost 3,000 miles to reach tidewater. One solution may be the sale of the oil to the Brazilian interior, and no doubt this possibility is being examined. There have been four completions at Aguas Calientes of which the last two were producers.

Ecuador holds promise of important drilling activity in the future. International Petroleum Company is engaged in geophysical and geological reconnaisance work on its 10,000,000 acre concession lying between the Pacific and the Andes and just north of the Santa Elena field. Of even greater interest is the huge 25,000,000 acre concession recently obtained by Shell east of the Andes. The center of this concession is 275 miles east of the Santa Elena field and approximately the same distance northwest of Iquitos on the Amazon. The northern boundry of the concession adjoins the Colombian border. Should production be developed here in the future, some solution would have to be found for the problem of shipping the crude eastward across the entire continent via the Amazon.

Looking to the 20,000 FT. WELL

By Ernest K. Parks

Consulting Geologist and Petroleum Engineer, Los Angeles, Calif.

An Inquiry Into Physical and Economic Limits of Depth by Mr. Parks, a Petroleum Engineer Whose Experience Includes Service with the U. S. Bureau of Mines and 14 Years with California Standard. As a Member of the A. P. I., AAPG, and AIME He Has Delivered a Number of Papers on Oilfield Exploitation and is Thoroughly Familiar with the Problems Discussed on the Following Pages.

CLEARANCE~THE LIMIT IN OIL WELL DESIGN

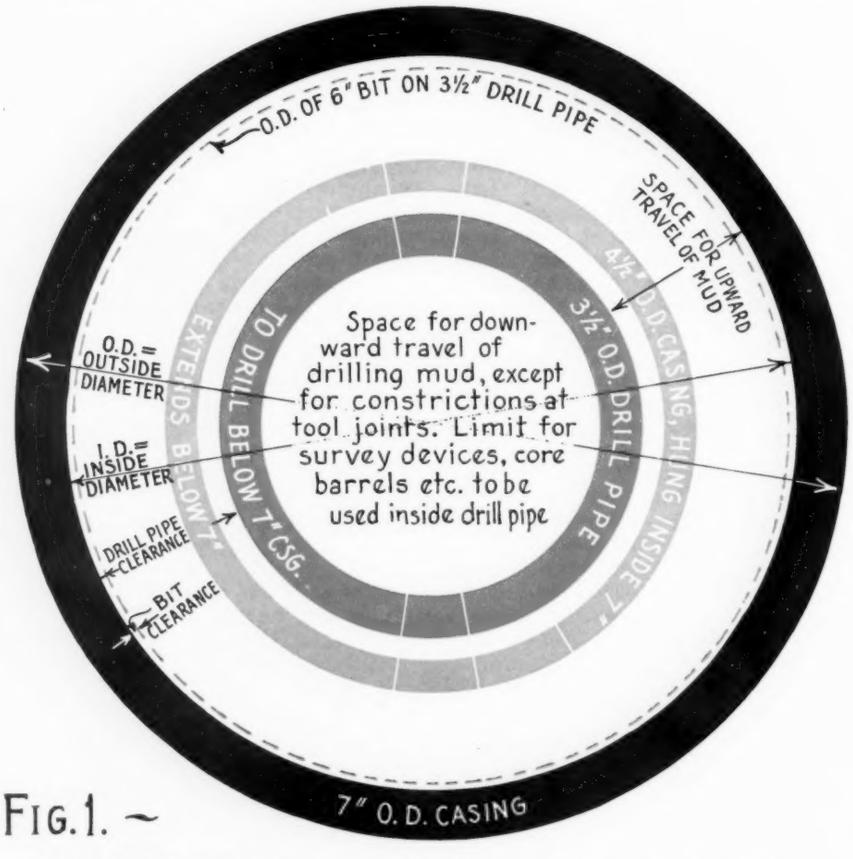

O.D. OF 6" BIT ON 3½" DRILL PIPE
SPACE FOR UPWARD TRAVEL OF MUD
4½" O.D. CASING, HUNG INSIDE 7"
3½" O.D. DRILL PIPE
TO DRILL BELOW 7" CSG.
EXTENDS BELOW 7"
Space for downward travel of drilling mud, except for constrictions at tool joints. Limit for survey devices, core barrels etc. to be used inside drill pipe
O.D. = OUTSIDE DIAMETER
I.D. = INSIDE DIAMETER
DRILL PIPE CLEARANCE
BIT CLEARANCE
7" O.D. CASING

FIG. 1. ~

The Oil Well Designer must "Go Around In Circles" as shown above, illustrating some of the clearances involved in present deep wells. The outside rim of steel establishes the absolute limit of all future work, hence the urge to drill in "Open Hole" as far as is considered safe.

This diagram shows that deep wells are not matters of thousands of feet but a problem of inches.

Record depths during the past ten years have been reached by the following wells:

1938	Continental Oil Co., Calif.	15,004 ft.
1935	Gulf Oil Corp., West Texas	12,786 ft.
1934	General Petroleum Corp., Calif.	11,377 ft.
1933	North Kettleman Oil and Gas Co., Calif.	10,944 ft.
1931	Penn-Mex. Fuel Co., Vera Cruz, Mexico	10,585 ft.

Distinction is short lived, not because there exists any desire merely to drill deep to make a record, but because bona fide search for petroleum leads to deeper exploration. Another reason for the temporary nature of the record is that technique and equipment are following up the course set by the deepest wells. It is a natural result that the limiting factors which are being continually revised to improve routine performance in drilling deep wells, allow the occasional well to be drilled far below the depth for which the equipment is designed.

Deepest wells are not so planned. They happen. The prospecting is, of course, presumed to require some estimated maximum penetration, and equipment for such a test is secured. It then develops that still deeper drilling seems justified and, except for some few changes, the work proceeds until the operator is satisfied that he has exhausted possibilities. In the course of this process records are broken, and, more important, deeper producible petroleum reservoirs are discovered.

There have been many failures in attempted exploration because it was impossible to drill to the required depth. An outstanding example is the Kettleman Hills structure which was a prominent possibility prior to 1914, but had to await development in the art of drilling before an actual discovery was made fourteen years later.

At this time a similar situation may exist. Geological conditions as between explored structures at depths below 10,000 feet and geophysical data in the same area may disclose possibilities now deemed impracticable if not impossible. This situation will cause deeper drilling until the possibility becomes an attractive venture.

In the meantime, more wells are being drilled deeper. A routine deep well is currently one of 10,000 ft. or more. In 1938 209[1] wells had been completed below that depth the world over, and by January 1, 1940, this total had increased to 382. This means that in the last year alone the number of completions exceeding 10,000 ft. were 80 percent of the total for all of the previous years, the record going back to 1931 when that depth was first reached. There are only ten wells of this class outside the United States.

The 10,000-ft. wells are distributed throughout 41 fields in the United States where the consequent discoveries have been estimated to total 670,000,000 bbl. of oil. The operating profit of this success is another matter, and one cannot evaluate the discoveries without much more information than is afforded by generalities. The facts are that wells of 10,000 ft. or more are being drilled in appreciable numbers, and one may assume that results justify the operators' efforts. The profit to the national economy is far greater than the profits of the operators, who have only what is left after costs of successful and unsuccessful exploration, exploitation, royalty, taxes, and forfeited titles.

In California, there are 101 wells of 10,000 ft. or more, and they have a rating of 304,000 bbl. per day of estimated demonstrable production. This shows that the potential rate is commercial, which is the first essential of a pay out. Other deep wells are in Louisiana and Texas, but the probability of future success cannot be limited to three states.

Although these figures indicate that deep wells have possibilities, the actual current deep completions in the United States are less than one percent of the 27,900 wells per year average for 1938 and 1939. The average drilling depth over the entire United States in terms of average footage per well is only a little in excess of 3,000 ft. and the deviation from this average has not been noteworthy since 1936.

The fact that some 40 fields are in the deep well class is far more impressive than the low drilling ratio. For example, out of 259 new fields found in 1939, 22 were of 10,000 ft. or more. This is almost 10 percent and more than ten times the proportion of deep wells completed to total wells drilled. The rating of these discoveries remains to be seen, but using current estimates, it is found that deep fields were responsible for almost one-third of the year's additional reserves, as indicated in the accompanying table. This again illustrates that considering the small frequency of the 10,000 ft. well, it is remarkably effective.

Comparison of Deep Well Discovery Reserves, 1939

Total Reserves Added (A. P. I.)[2]	340,667,000 bbl
Deep Well Field Discoveries	111,000,000 bbl

[2]Quarterly, Vol. 10, No. 2, Apr. 1940—American Petroleum Quarterly.

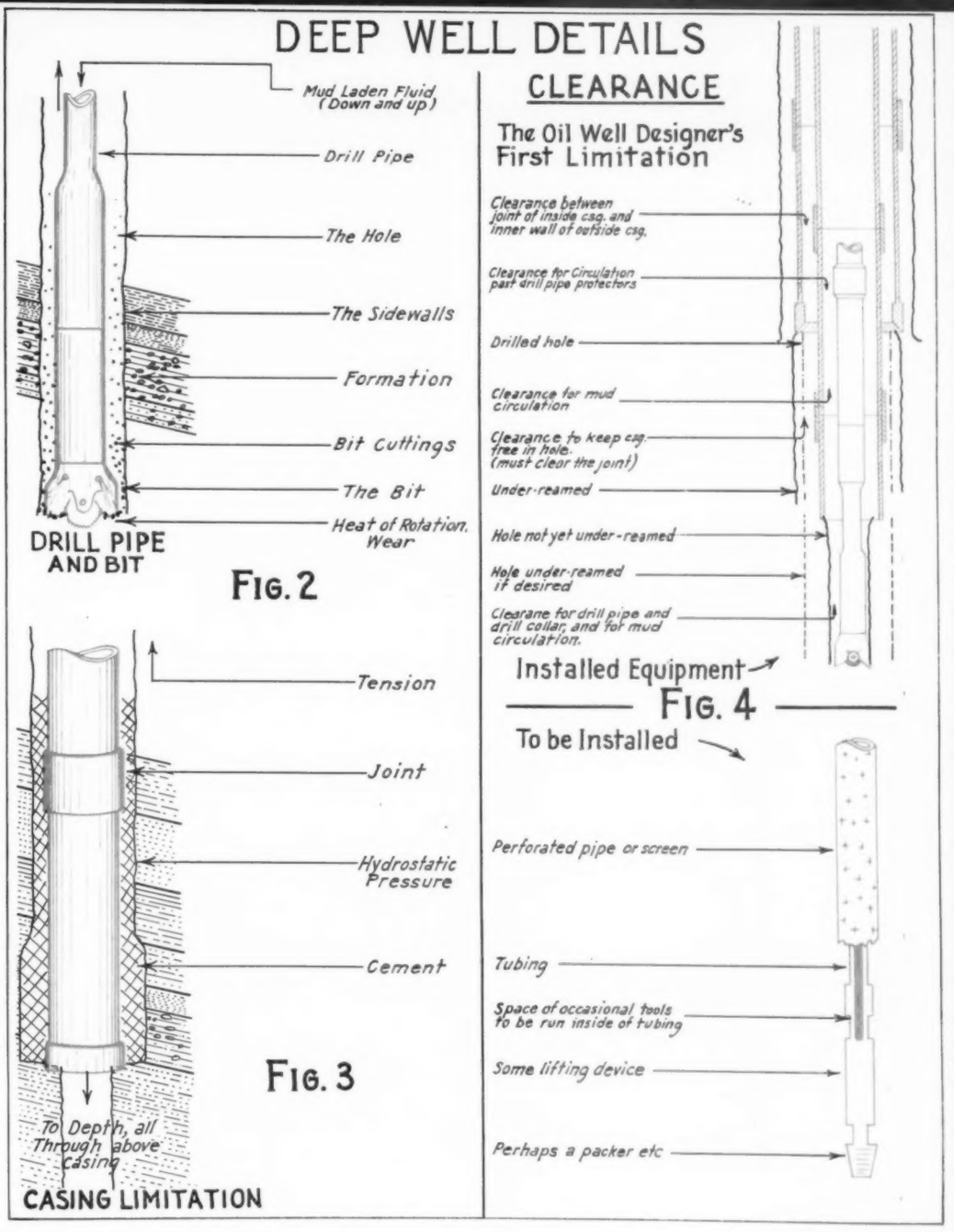
Wells below 10,000 ft. are still unusual, but are not distinguished by that depth alone unless they exceed the 15,000 ft. record, which is 5,000 ft. ahead of the present deep well class. Of the 171 deep wells drilled in 1939, fifty-two exceeded 11,000 ft., thirteen exceeded 12,000 ft., eight were below 13,000 and two below 14,000 ft. This shows a reaching out effect presaging a greater number of deep wells, and, of course, greater depths.

Depth offers an incentive to exploration, rather than acting as a deterrent. In reviewing histories of discoveries, the success of drilling deeper in known fields is so frequent that until a deep test is actually made to some conclusive end the possibility of deeper sands is considered almost a real asset. This possibility influences lease agreements, land values, and actual drilling programs wherein larger casing may be used to take care of requirements of deepening wells.

In the case of original deep sand discoveries of new fields, the term deep is a progressive one. As the drill and crew became capable of greater depths, there has always been a probable structure awaiting a test, and those who held title to property for years, in faith that sooner or later their holdings would be accessible to the drill, have been richly rewarded for confidence in progress of the industry.

Deep exploration is a natural outcome of vertical prospecting in the old mining conviction that there is a fortune a few feet ahead. Spurred by the proof of this idea, plus actual development of equipment to care for the deeper exploitation, the geologists proceeded to investigate deeper possibilities and recommended areas with the objectives far in advance of actual drilling practice. Then the search for deeply buried structures passed the stage of a real geology by direct observation,

[1]For this and some other statistical data on deep wells the author is indebted to Oil Weekly, Jan. 29, 1940.



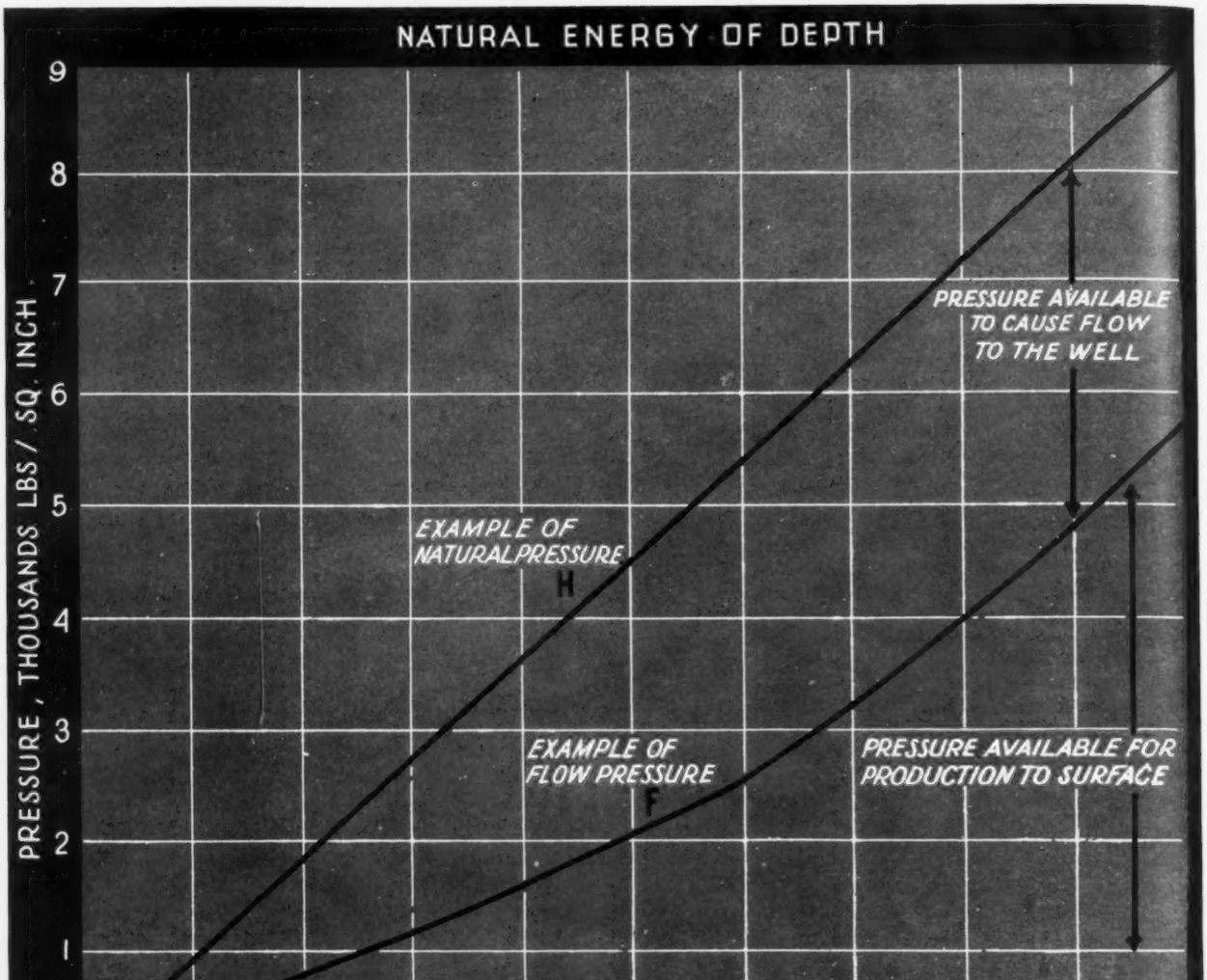


Figure 5

and led to the geophysical methods, which now set the goals for the deep wells.

If one has, say, $150,000 at stake in a test well, and has not encountered a positive end of his possibilities, such as a granite basement rock, he is prone to assemble another $10,000 and then another to have a look at the next few hundreds of feet. Many times his exploratory drill hole is of key importance to regional interpretation and therefore he can enlist aid in dry hole contribution from those who desire to see the test proceed to a definite conclusion.

A natural incentive to the geologists was depth, because the plane table, Brunton compass and hand pick finally uncovered all but the most isolated of surface structures, and this long in advance of actual discovery of oil in those structures. Thereupon, the geologists had either to go to foreign parts, retire, or go deeper. The latter course was followed, and those who venture into other countries now go not only with the elementary equipment but with the geophysical apparatus as well. When a geologist who has been a successful oil-finder is convinced that he has an oil field, the mere fact that it lies ahead of the current drilling attainments is no end to his project. The drill must go on down, and it does.

Deep wells are drilled in exactly the same manner as wells of but 4,000 or 5,000 ft. Elementary rotary tools twisted a bit by means of drill pipe through which mud was circulated. At intervals deemed necessary, casing was run into the hole, and the process continued. Only the equipment and the technique has changed. Therefore, a discussion of deep well drilling involves the subjects, not the method. It is quite true that items which were once of no consequence are now very important, and vice versa.

Let us enumerate, not for the benefit of those who know all about the subject, but for some who may not be conversant with the details. In earlier days, one simply built a derrick of the usual dimensions and set it on wood sills or concrete blocks designed and poured on the spot. They were strong enough but depth added new loads, mounting crew and equipment cost demanded speed, and these two factors required strength plus size. Now the derrick foundation and the derrick itself are each specialties which occupy hundreds of engineers.

With earlier wells, the driller selected a depth at which he desired to land a steel casing. He knew he might stick the pipe above the desired depth, so he drilled a large hole and set a large casing. He also knew he might miss his guess as to the correct place to land the pipe. He therefore selected casing large enough to allow the insertion of another casing if the first one was incorrectly placed, and still another if the second attempt was

unsatisfactory. Obviously, as wells were drilled deeper, the operator could not afford to buy and install five to seven thousand feet of casing on the trial and error basis. The remedy for this situation was engineering; that is, fact gathering and an interpretation with a cautious amount of planned experimentation.

A number of inquiries made of responsible persons failed to disclose any reaction indicating that the 20,000-ft. well would be impossible. A typical impression is given by J. R. Pemberton, Geologist and former Oil Umpire for California, who says in a personal communication to the author:

"With the passage of time, the easily found shallow oil fields have been developed and each year sees drilling progress to greater depths in the earth in search of more petroleum. The technique of drilling, completing and caring for a deep hole has been improved and things unbelievable five years ago are matter of fact practices today. With deeper drilling there has come, as hoped, deeper discoveries and in the minds of geologists, competent to form opinion, there very probably exist in many places oil deposits which may lie as deep as 20,000 ft. from the surface.

"As long as there is adequate oil at shallower depths one might believe it folly to seek oil at greater depths. Yet when one delves into the intricacies of supply and demand, it is necessary to think in terms of 'whose' supply and 'whose' demand. Thus in spite of the fact that some companies may have a surplus of supply and a small demand, other companies may have a shortage in supply and an increasing demand. Thus there are always found individuals with adequate financial resources and abundant engineering talent who are willing to back their own desires with action and it must not therefore be surprising if some day we have on the horizon a man who announces he is going to drill a well 20,000 ft. deep.

"The pioneering spirit, coupled with the gambling spirit of many of our leading oil producers is a thing which leads them to leave no stone unturned in an endeavor to get more oil even if they must drill to deeper levels. The fame that comes to the first man to drill a 20,000 ft. well and make discovery of a prolific oil pool at that depth is enough to warrant some people in making the attempt. In others, there will be the actual necessity to get more oil for their business which will force them to drill deeper than ever before.

"Within the realm of pure science alone, much is to be learned in drilling a hole 20,000 ft. deep. The geologist, physicist and the chemist would like to know what the conditions are that far into the crust of Mother Earth.

"Today we are thinking about the possibilities of a 20,000 ft. hole in much the same way we thought of a 10,000 ft. hole in 1926 and 1927, because at that time we were concerned with the uncertainty of cost. We now know that the cost of the first 10,000 ft. hole was far greater than is the cost of drilling such a well today and the pioneer who first attempts a 20,000 ft. well, although making his own calculations as to its cost, will remember that if he is successful in obtaining oil at that depth, his subsequent wells will cost far less than his first well. I am so optimistic by nature as to feel confident that not only will some one actually desire to drill a 20,000 ft. well but that engineers will attend to all details and that the hole will actually be a reality."

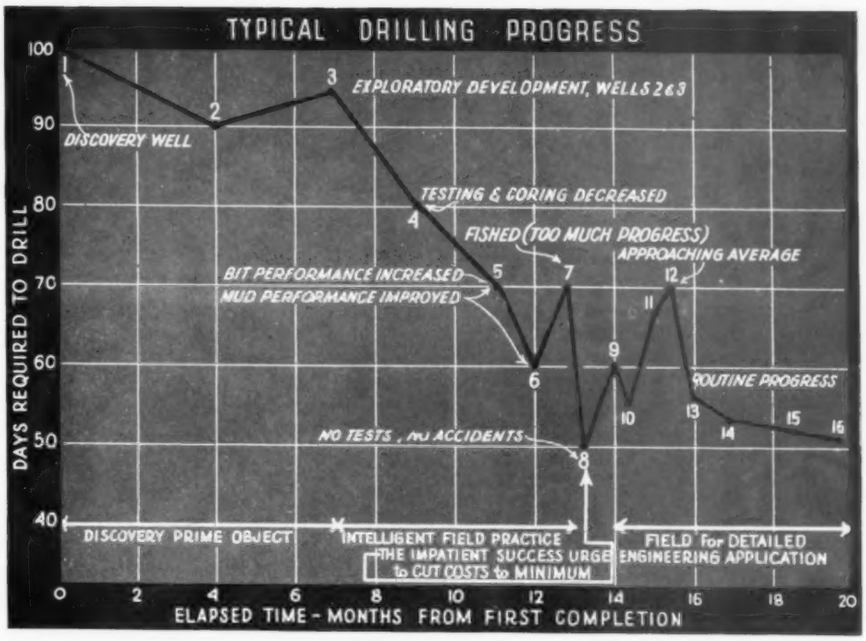


Figure 6

The contribution to economical drilling by the elimination of unnecessary casing was not all profit. Tests are necessary. The tests disclose geological data as illustrated by the coring of formation, or afford geophysical comparisons as exemplified by the electrical logging system, or are on actual demonstration of productive performance as is the case with a formation tester. These tests themselves are now an expensive item, and engineers are at work to develop other means of obtaining the necessary data. Attempts are made to substitute the cuttings made by the bit for geological samples, and to make other use of mud in a continuous series of observations to detect gas and oil which may actually be contained, or to determine conditions which could be inferred from physical changes in the mud itself.

These instrumentalities for determining facts are not luxuries. Deep wells are too expensive to be undertaken in a haphazard manner. Of course, once a structure is discovered, a more or less routine program can be worked out, decreasing the necessity for some tests and the frequency of others. However, the tests themselves have indicated that geological continuity is not what it was once supposed to be, especially in horizons comprising alternating sands and shales from 50 to 2,000 ft. in vertical extent.

All this means that a modern deep well requires a technical staff, but not only for subsurface studies of a geological engineering nature. The mechanics of the equipment and its use is another field, and so specialized that in larger organizations, many individuals devote their entire time to the subject.

The relative importance of various components of deep well practice is difficult to evaluate; and as intensive study continues, the solutions to some worrisome problems have been in the consideration of a factor which had been entirely omitted from the analysis. As an example, operators bought a great excess of new pistons and liners for mud pumps for years before they adopted the simple expedient of straining the mud through a vibrating mud screen adapted from the mining industry. Again every well founded engineer learned in the early stage of his education that there was a mechanical equivalent for heat and that this was determined by rotating a paddle in water. Yet brake bands and hoist drum brake rims wore out by the thousands before a braking system based on the elementary principles of Dr. James Prescott Joule (1818-1889) was adopted.

These examples are but a few of the important advances which have made deep drilling possible. The improvement came as a result of demand, which was intensified with deeper wells, mounting costs, and the free competition which still prevails in this unregimented industry.

OBSTACLES

Space does not permit a history of practice; but prior to considering the specific obstacles to a very deep well, one may profitably inspect the essentials of current practice, which varies decidedly with local conditions which differ economically and physically.

Before any details, it is interesting to note the statement of General Superintendent A. H. Bell in July, 1938, MINING AND METALLURGY who drilled Continental Oil Company's record well. He says, "The only unusual features of the drilling were the chemical treatment of the mud to overcome caving shales, and the fishing job made necessary at 11,584 ft. by the dehydration of the heavy drilling mud on the face of the sand encountered at that depth." As for drilling to 15,000 ft. or more, he continues, " . . . a slight and unintentional angle of inclination would cause failure of the drill pipe,

already loaded to its safe tensile limit from dead weight alone, unless intermediate protection casing strings were used to eliminate the friction of the drill pipe against the walls of the formation. Until better technique is developed for drilling perfectly straight holes, it is doubtful if holes of 15,000 ft. or deeper can be drilled successfully in fields with steeply dipping beds."

This project, started with "the intention to drill to 9,500 ft." was described by Bell in March 1938, WORLD PETROLEUM after reaching 14,000 ft.

The steel derrick was 122 ft. high, the engine, draw-works, and pumps, were not extraordinary, and the wire rope was 1⅛ in. diameter lang lay type. Four 100 H.P., 250 lb. pressure boilers were used; and in addition, there was a separately fired superheater with steam at 480 deg. F. Drilling was routine in the early stages, and a string of 10¾ in. seamless casing weighing 55.8 lbs. per foot was run in and cemented at 5,512 ft. This comparatively small casing diameter is proof of the statement that no record was in mind at the start. Drilling proceeded with 4½ in. diameter drill pipe to 11,684 ft. This means that there were 6,072 ft. of uncased hole below the 10¾ in. casing. Here came an accident, and it became necessary to fish out the drill pipe, and to drill around the drill collar and the bit. This job required 44 days. This done, the hole was again protected with a casing, seven inch diameter, 30 lbs. per foot, to 11,573 ft. and cemented. This is expert work but goes fast, speed being one of the elements of success. The job took 8½ hours, exclusive of the time to pump in the 800 sacks of cement. Further drilling was done with 3½ in. diameter drill pipe, rotated at 75 r.p.m. The mud was circulated at 240 bbl. per hour with an input pressure of 1,250 lbs. per sq. in. With this procedure, and using six inch diameter rock bits, the additional drilling time to the then world's record depth of 12,876 ft. was thirty two days.

The following items appear as limitations in drilling to 15,000 feet or more.

1. The hole must be straight.
2. The mud must be constantly controlled in physical character, and circulated at rates consistent with the circumstances.
3. The wire rope used in hoisting drill pipe from 15,000 ft. is excessively loaded at the per line load of 27,000 lbs. with ten lines strung through the blocks, the 1¼ in. wire rope of plow steel having almost 23,000 lbs. recommended maximum load with a safety factor of 3.
4. The 3½ in. drill pipe at 15,000 ft. is loaded to the limit yield tensile strength under normal conditions, allowing no margin for extra pull in case the bit is stuck or other difficulties arise. The normal maximum load was computed from measured pulls as being 62,800 lbs. per sq. in., whereas the average manufacturer's test yield for the pipe used was 60,000 lbs. per sq. in.
5. Casing for the well.

Examination of these limitations, shows that the actual drilling art is as always a prime consideration. The straight hole requirement should not be insurmountable.

The advanced technique that Mr. Bell calls for may come with demand. Straight hole has so far not been of such paramount importance and common practice is to limit deviation to three deg. or less from the vertical.

Experts in the surveying of holes are already very accomplished in the art, and those who specialize in directing the course of bore holes are able to guide the drill to preassigned locations. Thus, the difficulties are increased by steeply dipping beds, as Mr. Bell suggests, but the industry has not yet undertaken in the average deep venture to restrict deviation to the extent stated by Dr. Bell.

MUD

As for the mud, this should be no effective barrier to depth. There will be problems, and some expensive failures, but operators who realize the problem will avoid much trouble by providing for experienced mud control from the very start of the project. The art of mud design and mud practice is rapidly becoming a specialization and in recognition of this fact, it is in order to regard the comments of Mr. W. L. Heater, manager, Pacific Coast Division, Baroid Sales, whose sole concern is the mud problem. In a personal communication to the author, he says, in respect to the mud requirements for a bore hole to 20,000 ft. in California fields, "no great difficulties should be encountered.

"In considering the weight of drilling mud which might be required, it is quite evident that the relatively small diameter of a bore hole would not affect the competency of the earth's crust. In other words, if shale bodies were encountered at depths approximating 20,000 ft., it should not require any greater hydrostatic pressure to hold them in place than if they occurred at say 10,000 ft. A safety factor, as far as weight is concerned, should be carried in excess of 62.5 lbs. per cu. ft. as it is possible that salt water flows, oil or gas might make this factor necessary to prevent infiltration into the drilling mud. While it is possible that excessively high pressures might be encountered, it is unlikely that there would be the necessity of adding additional weighting material, such as barytes or iron oxide, as greater depths were penetrated.

"The hydrostatic head of a mud made from nothing but concentrated colloidal matter and water, weighing 65 lbs. per cu. ft., at 20,000 ft. would be 9027 lbs. per sq. in. If a 70-lb. mud were used, the hydro static head would be 9721 lbs. per sq. in., leaving a safety factor of 694 lbs. per sq. in.

"When shale of the disintegrating or sloughing variety is encountered in drilling, experience has proved that in most cases there is a critical mud weight which once attained will very greatly minimize this sloughing condition. Many times, operators will increase their mud weight continuously up to a certain point to eliminate tight hole but will get discouraged with the results and will not carry the mud weight to a high enough point to eliminate the difficulty. The higher up the hole this type of shale occurs a relatively higher unit weight of mud will be required. This condition is greatly simplified with the increased depth of the well, such as a 20,000 ft. hole, due to the natural increase in hydrostatic head.

"It appears that the chief requirement of a mud for this deep drilling would be to have relatively high colloidal content which would tend to keep water losses to a minimum and to build up only a very thin cake on the walls of the hole. The mud cake built with any mud at 20,000 ft. will be thinner, denser and more compact than at a lesser depth. This increased density of mud cake also tends to reduce the permeability of the filter cake thereby also reducing the water loss.

"Of greater concern than the adjustment of mud weight to very deep drilling is the detrimental effect of temperature. From the information available, I think it is estimated that temperatures of 400 deg. F. or less would be encountered in a well drilled to 20,000 ft., if the drilling were being done in a deep, sedimentary basin. If the drilling occurred in an area where there was a basement complex of granite or schist, or in a closely folded area, higher temperatures would be expected. Elevated temperatures have a detrimental effect on all drilling muds. As a rule, native muds are detrimentally affected by high temperatures in the respect that their water loss and cake thickness are both greatly increased. Straight colloidal muds show very little change in water loss and cake thickness in the presence of elevated temperatures and it would, therefore, appear to be very advantageous to use as light and as highly colloidal a mud for exceptionally deep drilling as safety would permit. Moreover, a mud of this type can absorb or assimilate a much larger percentage of inert solids picked up from the hole than a mud with a small percentage of colloidal material. Muds of this type also yield more readily to chemical treatment and due to their fluidity they are much easier to circulate. Chemicals for the reduction of viscosity and gel-strength are also adversely affected by elevated temperatures and lose their effectiveness more readily under these conditions and a 20,000 ft. well would probably require a relatively greater expenditure due to the increased quantity required. There are, however, some new developments in chemical treating which indicate that the degree of chemical treatment can be stabilized considerably in the presence of elevated temperatures.

"It is our opinion that the correct formulation and careful control of drilling mud, while of primary importance in the completion of a 20,000 ft. hole, should not present any undue difficulties. A highly colloidal, relatively low viscosity mud can be used at decreasing unit weight as greater depth is attained, which is also advantageous in the event of encountering loss of circulation."

EQUIPMENT

We next come to the wire rope problem which involves the entire hoisting apparatus. The changes which will be needed in this equipment are obviously to be radical and costly. It may be that wire lines may be abandoned for some other means, such as an hydraulic elevator. This problem, while of no small importance and definite present limitation, is a surface feature which can and will be worked out when it appears that the result will be worth the effort. The derrick is already a crowded place and any appreciable change in a hoisting system is quite likely to affect not only the shape and design of the derrick, but also the customary methods of handling the long sections of pipe that must be arranged in stands as pulled out of the bore hole. Whatever the cost it will not all be added direct cost for efforts to reduce the

wire line problem may eliminate much of the expense which is already a considerable item.

The drill pipe needs to be stronger. Mr. Bell states that in 1938 pipe companies were prepared to furnish 100,000 lb. yield point pipe, and would supply steel of 120,000 lb. quality. This would double the present 60,000 lb. pipe he used and make a 20,000 ft. load possible. One would not say there was then no drill pipe problem, but it appears nearer a solution than the hoisting question.

Casing is another pipe problem, in which the factor of depth requires thickness to resist collapse. The heavier the pipe, the greater the tension, and this in turn reduces the resistance to collapse, so that design on the lower end influences the entire length. If one were to set out to drill a well to 20,000 ft., he would attempt to coordinate the complete program, but the probability is that this will not be the case. The first hole of such depth is most likely to occur as an extension of some less ambitious objective.

It is not the present intention to design casing and the many methods of installing it, and in considering a 20,000 ft. well one should not imagine some trick practice with present material which will enable the very first accomplishment. The usual routine of the deep well of the future is a far more useful conception, and this, it is admitted, will require an inventive mind.

In order not to hedge on the problem, it will be assumed that only the last 500 ft. are in a productive horizon and that it appears advisable to protect the oil bearing formation from water which might enter from above. One could present several methods of approach along lines of present practice, but whatever the detail one fact is paramount; the casing must be thick walled and of a tensile yield point of some 120,000 lbs. per sq. in. This means that the casing is to be expensive, for the supply will be small until the number of deep wells has increased sufficiently to have developed a demand for especially adapted casings.

A vital element in the entire casing program is the length of open hole which can be drilled. The last few years have seen remarkable strides in open hole progress. The famous Continental well was drilled from 5,512 to 11,584 ft. in open hole, and also from the latter depth to the bottom at 15,004. Such accomplishment, with due credit to the crew and supervisors, is a direct result of improvement in mud technique. Mud is a competitor of steel. Mud practice will therefore directly affect the casing program of the 20,000 ft. well in the same manner as it has already eliminated hundreds of thousands of feet of protective strings of casing.

It would seem logical, therefore, that one could count on 5,000 to 7,000 ft. of open hole in California, and in any other place where mud control has been and is likely to continue effective with depth. This would place the last protective string at 13,000 ft. The balance of the casing would depend upon requirements and methods, with the probability of one additional string to bottom at 20,000 ft., cemented to two or three hundred feet above the oil horizon.

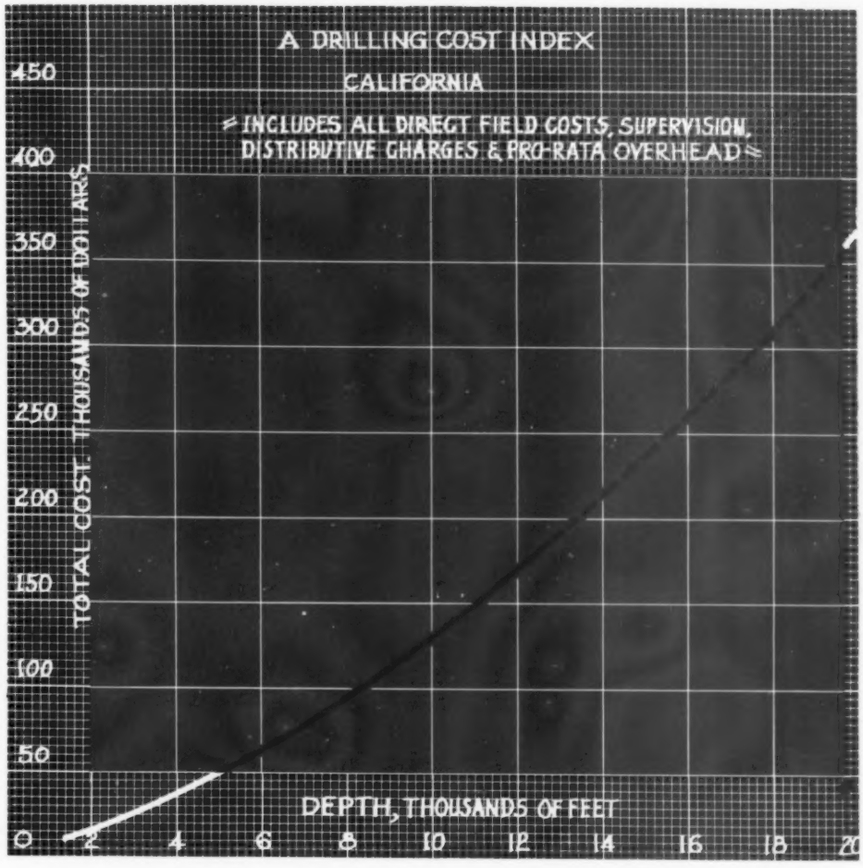


Figure 7

Regardless of auxiliary design involving particularly the drill pipe and mud system, the force of circumstances tends to reduce the diameter of the casing which can be used. High tensile strength is an alternative to thick walled pipe. With constant use throughout industry for high tensile alloy steels, and a growing need for such a product in oil drilling it is reasonable that efforts will be continued to supply tubular goods in ranges beyond those now in use.

With improvement in all departments, coordination of technique, and field application of engineering experience from present deep projects it would be anticipated that the 20,000 ft. well would resemble the present 15,000 ft. well, with possibly an 8 5/8 in. casing at 13,000 ft. and a 5½ in. casing below.

Cementing practice has become specialized to the extent that this phase of the drilling work is in the hands of experts who devote their entire time to this one subject. Difficulties of depth are time to accomplish the placing of cement, temperature, reduced clearances, and the eventual subjection of the cement in place to much higher differential pressures. Like any other important item, the cementing is vital to success, but it does not appear that the 20,000 ft. well will have to await any drastic revisions of material or method. This statement is not to be construed that there are not now serious misgivings as to the ultimate efficacy of deep well cement jobs. Like mud, cement plays a large part in the elimination of steel casing and there will continue to be a strong economic pressure to finance research, experiment, and new methods.

ENGINEERING

Without formulas, and hence not in sufficient detail for the engineer, but to give some idea of depth as a problem, it is worth while to note elemental factors.

Geologically, greater depth means an increase in temperature. This increase is not the same in any region, but varies to such an extent that earth temperatures have been closely studied and an excellent review of the subject with emphasis on California is given by French[3] who shows not only variations as to locality of wells but with different circumstances such as static conditions, flowing, or following a mud circulation period. With temperatures as high as 275 deg. F. at 13,000 ft. it is quite possible that the California value at 20,000 ft. may be over 400 deg. F. Higher temperatures may be encountered and if so will cause some concern for even now diligent attention is required as to the bit cooling and mud conditioning. Temperature data are currently secured during test runs of geophysical devices and depth pressure recorders, and the prospector will probably have available information on the expected temperature.

Deeper sediments will not necessarily be

[3] R. W. French, Drilling and Production Practice, 1939, A. P. I., p. 653.

unproductive on that account. The nature of the porous rock with respect to its physical properties is far more important than depth. Compaction will of course be greater, but porosity and permeability will be largely a matter of chance, except insofar as exposures or samples of the objective series of formations may indicate. A decreased permeability if encountered, will be offset by the decreased viscosity of petroleum at the greater temperature.

The 20,000 ft. reservoir will be same as those now encountered, except that its contents will be warmer. This difference is important in that pressure and temperature are two fundamental variables of the condition of petroleum fractions. As soon as a discovery is made the distinguished pioneer would do well to obtain a complete analysis of the thermodynamical relations of the product he has discovered. It is useless to speculate upon the probable hydrocarbon content. The principal fact is that it will be fluid and will be recovered by the usual methods, plus modifications of technique which will be required by the great investment in drilling the wells.

Greater pressure as expected with depth, will be advantageous in production, but the depletion of pressure may bring on unusual problems of water infiltration by reason of the great differential which would be possible between the undrained water sources at native pressures and the reduced pressure in the oil and gas reservoir. Selective production from so-called zones will be more difficult. It is also obvious that economics of pressure maintenance will be affected by high input pressure and the cost of input wells.

Mechanical effects of depth are increased tension on pipe, increased torque necessary to rotate drill pipe against the added friction of the hole, and greater friction losses in mud circulation. The formation pressure will require greater resistance to collapse in pipe. These factors will each have a multitude of results with respect to pipe joints of all kinds, steel specifications and the entire mud system.

Increased temperature and pressure will affect chemical and physical reactions. This will be of concern in mud conditioning, in considerations of corrosion of metals and in cementing.

Geophysical prospecting now outlines structures at 10,000 to 13,000 ft., and just as the areal mapper of 20 years ago correlated his observations with beds 5,000 ft. or more below the surface, so one may expect the geophysiast to work from whatever strata he may now find at practicable depths.

PRODUCTION

Production engineers do not consider depth a major problem. The reason is that natural conditions provide the energy and the means of making this energy available. Whereas the natural hydrostatic pressure of deep reservoirs is a formidable obstacle in completing the well, this pressure is the cause of production. Were it not for the fact that gas occurs with the liquid petroleum the operator would find that the oil column so nearly balanced the reservoir pressure that the rate would be be small and the flowing life short. As it happens the natural gas expands, provides energy, and also causes a light mixture of oil and gas which results in a pressure gradient less than the natural increase of pressure with depth.

Natural flow will cease when the declining reservoir pressure reaches a value which is equalized by the flowing column, and thereafter energy must be provided from the surface. The object of good practice is so to produce the oil and gas that a profit can be made with a minimum of natural energy being wasted, the principal concern being to preserve conditions which will cause flow of liquid petroleum toward the well.

Some operators have encountered conditions which favor the immediate addition of energy to the reservoir. This practice is known as pressure maintenance so well described by E. O. Bennet, in his paper on "Drilling and Production Practice", P. 113 A. P. I. 1938. Others prefer to wait until natural flow and subsequent gas lifting, which is the usual successor to natural flow, have reduced the reservoir pressure, whereupon a project to restore energy to the reservoir is adopted. This is repressuring. Each process is a gas injection procedure, and involves large present investment, the economics of which can not be detailed here.

Deep wells beyond the range of the rod-actuated pump, may be equipped with the hydraulically powered pump, or the submersible electric centrifugal pump, and if there is room enough in the well certain equipment may serve admirably to utilize low pressure gas. This equipment is of the intermittent flow type, such as the plunger lift, and various combinations of flow valves, packers, gas conduits, and exhaust chambers by which it is sought to lift a quantity of liquid by a pressure gas discharge and then reduce the pressure in the input chamber so that it may fill with another load. Also, there may be a combination of gas lift and pumping by stages.

It is quite obvious that as soon as natural flow ceases, the production process begins to be expensive, especially if complicated by emulsions, sand, water, wax, or hydrocarbon precipitates of a nature peculiar to local conditions. It follows, then, that there should be a lively interest in a general program for conserving the reservoir pressure, especially in such circumstances as the procedure appears to expedite migration of liquids to the well and avoid premature water.

Natural oil and gas reservoirs are of various types, with still more variable conditions of arrangement with respect to vertical distribution and areal extent. Consequently one cannot expect pressure maintenance projects to be as adaptable in one place as another. Furthermore, production methods which involve the entire reservoir are subject to cooperative arrangement with the several parties at interest.

Contemplation of a 20,000 ft. venture impresses one with the thought that competition at that depth under the law of capture may prove an expensive indulgence. Certainly no one will be interested in small acreage, and if the objective is large enough to interest more than one operator the probable development cost may be sufficient to compel a unit plan. These are always difficult, but in the extreme case now contemplated there will be less choice of action by all parties concerned, including the land owners.

The cost of drilling increases with depth in a curve with an ever increasing slope. That is, each average successive foot costs more than the previous one. One obvious reason for this is that although a bit may make equal progress at any place in the well, it takes a longer and stronger pull to extract the bit and greater wear and tear to go back into the hole each time. This simple reason is fundamental to the cost curve. However, once the job has been done there is an effective cost reduction because of gradual accumulation of information, resulting in decrease of exploratory measures and increase of efficiency.

The generalized cost curve of Figure 7 is based upon the usual routine drilling; that is, upon the average of the flat portion of Figure 6. The first venture to 20,000 ft. may well cost upwards of $400,000, but on this basis the routine wells may be reduced to $300,000, after making allowance for the progress in deep well drilling in the next few years.

Well spacing will automatically be conservative. Deep well drilling has already had a great effect in decreasing the density of wells. There will therefore be a trend toward long lived wells and this will influence design with respect to making the well serviceable for a variety of conditions and ease of repair. Fewer wells will in turn mean that more information per well must be obtained during the drilling stage. Wells will have to be strategically located, and not merely follow some pattern of so many acres per well as now designated in leases. Spacing the deep well, even now requiring all the skill the geologist and petroleum engineer can produce with the limited data available, will become a greater responsibility and those who pay the bill will have to recognize that more money will have to be spent for data, actual cores, geophysical measurements, laboratory analyses, production tests of formation intervals, extensive rate experiments, and sub-surface pressure measurements at intervals after completion.

ECONOMICS

Once completed the 20,000 ft. well will require a substantial yield to pay out, let alone render a profit. The interest charge alone will be for example $12,000 per year at four percent on $300,000. The taxes will be levied on the value of the reserves and unless this value is reduced by the cost of converting them to dollars the burden will be confiscatory. Even now the tax policy serves to restrict discovery. This is a fact agreeable to some, objectionable to others, but is important in the economics of oilfield exploration. As already stated the deep well program must support more direct engineering and technological supervision.

All these costs will make it impossible to offer the landowner any such attractive royalties or bonuses as is now customary. He must share the added cost or go on farming

the land. Of course there will be competition, but this will be tempered among well informed oil companies until it is demonstrated that such costly wells can be drilled and produced at a profit in the face of present high taxes and landowners' royalties. All this means that instead of being interested in the economic limit of production rate at the far end of the producing life, we must look at the survival rate, under which the operator can not stay in business.

One cannot justify exceptional exploration in times of slack demand for a product, but to get some idea of the circumstances which might prove an incentive the possibilities may be estimated. Right off hand if the operator expects a five year return of capital he is asking for a substantial daily rate.

Given the cost of a well any business man of oil producing experience can compute the needed return to satisfy his ideas of an investment, but to save the trouble let us look at some figures.

Suppose that the wells are eventually to cost only $300,000 each, and that four percent compounded annually is to be allowed as a minimum return. The royalty already expressed in percentage will as usual be the basic cost. Let the other costs be also reduced to percentage. Thus if royalty is 15 percent, taxes are 25 percent, and the other cost of production is 25 percent, the total is 65 percent. If the gross yield per barrel of product is $2.00, the situation is as shown in the figure, which illustrates two cases, a five year payout and one of ten years. The five year return requires 482,500 bbl., the ten year 537,500 bbl. These values are based upon constant daily rate throughout the life. Note that the required return increases much faster than a proportional ratio to costs. This again emphasizes that royalties must be kept down on costly ventures. The returns as illustrated show no profit, that is, no yield above the required four percent.

Agreements must be conservative with respect to the required number of acres to be drilled. A fundamental is: The more wells in a given reservoir the less will be the yield per well. No one can say in advance what the well spacing should be. This is not to imply that one could furnish an answer after discovery, but at least there is no sound basis for incorporating a well spacing agreement in the promotional stage of an exploratory venture.

The required yields at constant rates indicate a daily average rate, at 365 days per year, of 55 bbl. per day per 100,000 bbl on the five year basis, and 27.5 bbl. per day per 100,000 bbl. on the 10 year basis. Thus a required yield of 400,000 bbl. in five years would indicate a daily average of 220 bbl. per day; and a like amount in 10 years would be equivalent to 110 bbl. per day. Thus a comparatively small rate for a long time adds up to large yields.

The indicated yield requirements are per well and do not include preliminary expense. One dry hole or ineffective well would place a heavy load on the remaining wells. In view of the uncertainties of developing a property, let alone the hazards of drilling, it is quite probable that completed and producing wells will have to share an expense upward of 10 percent of their actual cost.

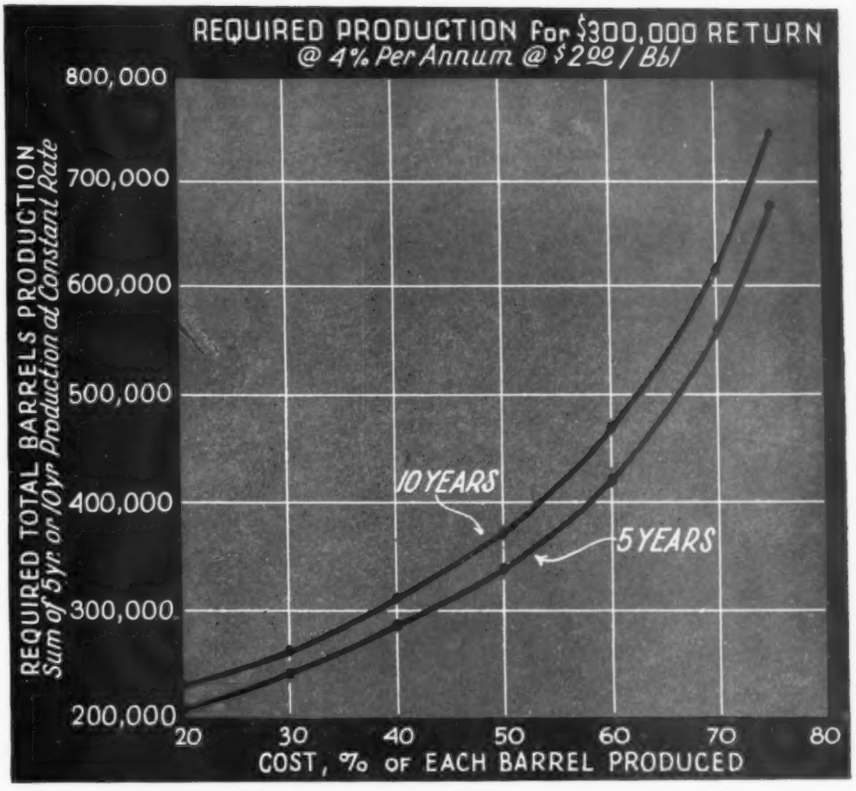


Figure 8

It appears that there will be no quick pay-out of the 20,000 ft. well under a pro-rata system, and if this situation continues, the operator with such a costly investment in one hole will feel the necessity of thorough inquiry into potentialities of his discovery before deciding upon another project.

As to the economic limit of production for the 20,000 ft. well, one makes no contribution to the venture in quoting some average performance one has in mind. It is, however, reasonable for those interested to inquire because the idea of depth is correctly associated with high costs. The over-all regulator of production method is depth pressure at the place of entry of oil into the well. The next factor is the gas supply. With high pressure, abundant gas, and absence of mechanical trouble with sand and wax, a clean oil well in an environment of low corrosivity is an asset indeed. But all this assumes one vital detail. The well must penetrate a reservoir of adequate potential yield in volume, and also in rate of output.

The question would be more to the point, but still subject to many provisions if one asked, "Granted a discovery, would the deep well be profitable during the period of mechanical lift, that is by some other method than natural flow or straight gas lift?" An answer is still quite unsatisfactory, because there are too many variables including the economic factors, and the cost of the mechanical device. Probably a general statement would be more in order than a pumping cost from 20,000 ft.

When gas lift ceases to be economical, the difficulty will probably be low reservoir pressure, that is a pressure insufficient to overcome resistance to flow at a commercial rate plus the back pressure exerted by the input gas. The remedy will be to relieve the back pressure. The process is a gradual one, unless the pressure decline per unit volume of total oil and gas production is too fast to warrant temporary installations.

CONCLUSIONS

1. **A well 20,000 ft. deep appears not only as a possibility, but as an approaching reality.**
2. **The chances for profit under present conditions are so narrowed that the 20,000 ft. well may be expected only as a result of some extended prospect.**
3. **There is no technological reason why such a well should not produce oil and gas at a commercial rate.**
4. **Development of the 20,000 ft. oil reservoir will require great geological skill and constant expert engineering supervision in order to reduce the element of chance.**
5. **The high yields required for a pay-out will greatly restrict the number of wells to be drilled into a unit reservoir.**
6. **The required high yields will tend toward an extension of the pay-out period.**
7. **The great cost will require minimum royalties, and a reasonable assessed valuation upon the discovery holdings in order to avoid confiscatory taxes.**
8. **The cost will discourage competition, and encourage unit operation of the deep well field.**

Huge Additional Reserves Wait on Improved PRODUCTION METHODS

By Lester C. Uren

Professor of Petroleum Engineering,
University of California

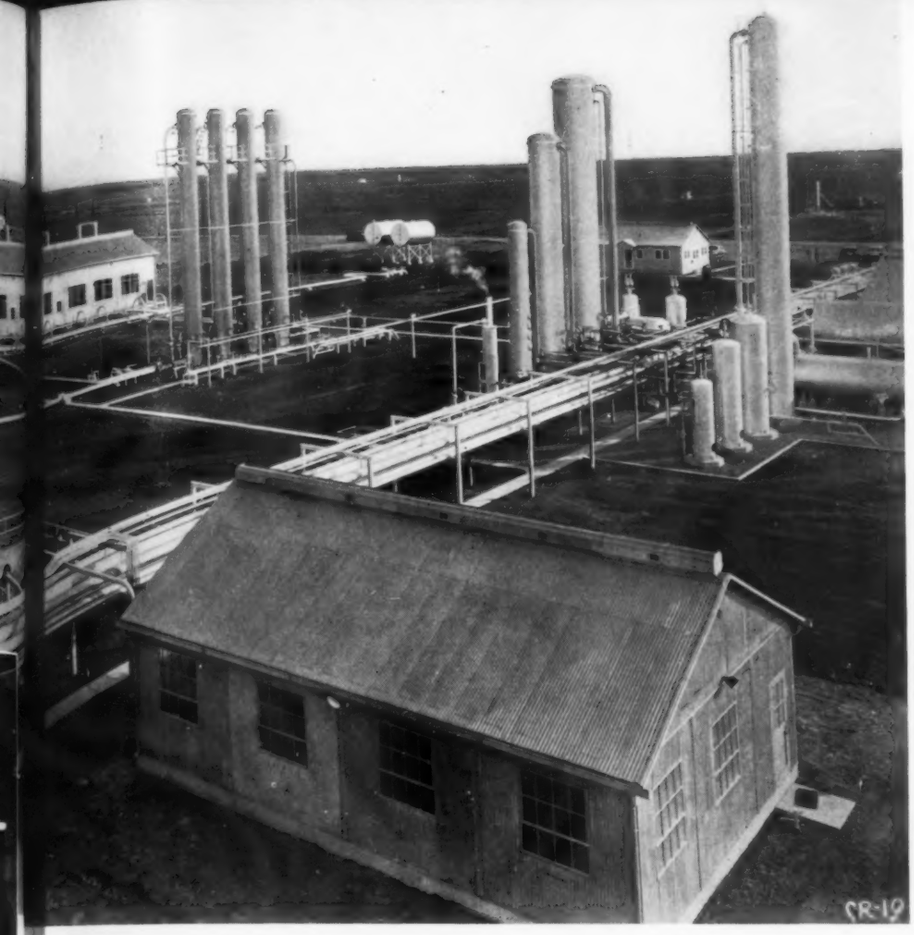
Drilling Costs Reduced 50 Percent in Last Decade—More Detailed, Complete and Accurate Information on Subsurface Conditions Available—But Even Most Modern Methods Render 50 Percent of Total Reserve Unrecoverable on Present Economic Basis.

Recycling operations such as the Coastal Recycling Corporation's Banquete, Texas plant pictured herewith with its five 800 h.p. Clark engines materially increase ultimate recovery.

To a certain brand of conservationist it has become traditional to charge the oil producer with unconscionable waste. He allows great quantities of gas to escape into the atmosphere just to get rid of it. Oil stands around in open sumps and tanks to evaporate and seep into the ground. He is so careless with fire and provides so little protection against fire hazards that much of the oil which is not lost in other ways goes up in smoke; and the producer deliberately burns much of the emulsified oil and other low-grade products that he destroys or runs to waste just because he lacks the skill to reclaim them. And this surface wastage that anyone can see is but a part of the iniquity chargeable to the oil producer. Most of the wastage occurs underground, under circumstances that make it difficult or impossible to determine its real magnitude. A large part of the total amount of oil present in our oil fields is left behind in the reservoir rock by reason of careless, primitive methods of extraction. That which remains behind is rendered worthless for future exploitation by failure properly to exclude water from the wells. Improper use of nature's expulsive forces wastes energy that might, if conserved, result in greater production of oil. Thus runs the story of the demagogue-conservationist.

How much of all this shall we admit? In earlier times and even today in certain fields and with some producers much of this indictment was and is true. But to apply such statements generally to the industry of today is utterly misleading and false. The great majority of operators and a very large percentage of the current supply of oil and gas are now produced with a high degree of efficiency and with all reasonable regard for proper conservation of our remaining resources.

A politician seeking for his own aggrandisement or selfish interest to discredit the



petroleum industry or those engaged in it finds it easy to produce evidence of instances of wastage and inefficiency sufficient to support his contentions before an uninformed and gullible public. Or, better intentioned persons, inspired by patriotic fervor and zealous in the interests of "future generations of Americans yet unborn", are misled by the welter of ill-considered statements and adverse criticism that often emanate from factional interests within the industry itself.

Generally speaking, the layman does not yet appreciate the vast improvements that have been made in oil production methods during the last decade or two, nor the increased production efficiency that has resulted from this improved technique. As a means of improving their public relations producers would find it greatly to their advantage to seek appropriate means of correcting the false impression that apparently still persists in the public mind.

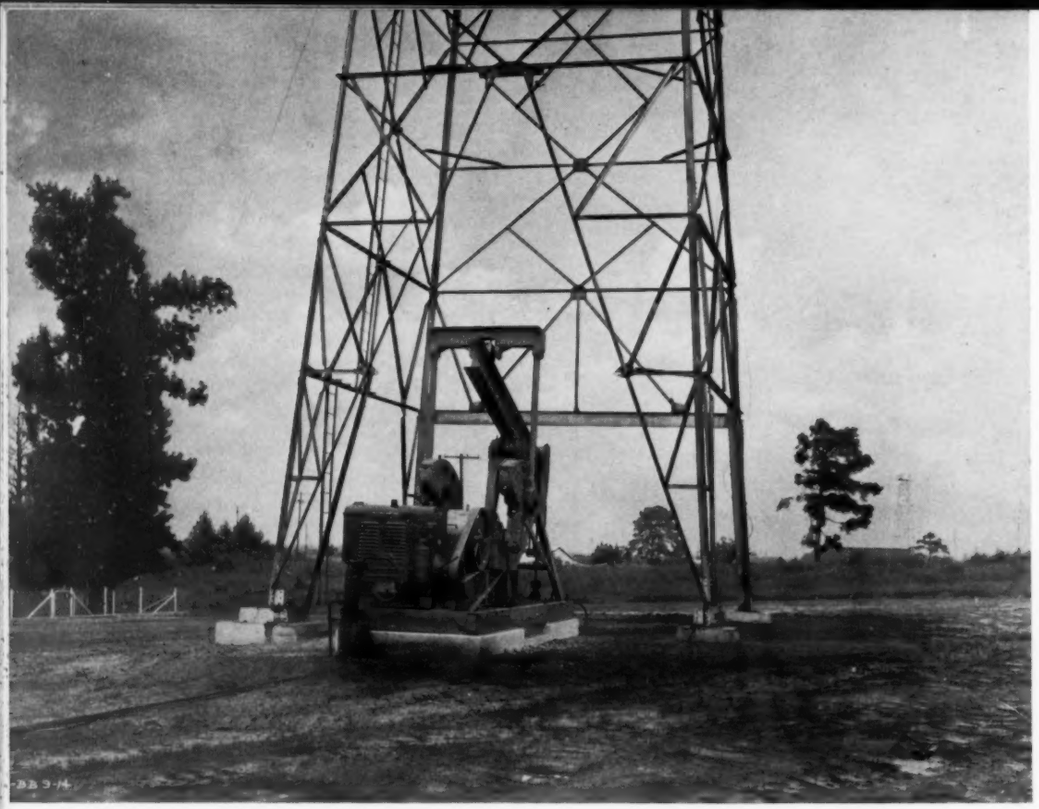
EFFICIENT PRODUCTION

Even in outline the story of the petroleum industry's effort to improve its efficiency and correct wasteful methods formerly all too common, is indeed an impressive one. Highly competitive conditions which were once responsible for much of the waste have now been supplanted, in many instances, by unit operations or cooperative agreements which permit application of the most efficient recovery methods. The industry has progressed from an era of unbridled, destructive competition to one of almost complete regulation and control in which an orderly program of exploitation is enforced by government authority or is attained by general agreement among the interests concerned. Operators in newly discovered fields are not permitted to develop flush production in excess of the market needs. Wells are conservatively spaced, with the purpose of avoiding gas wastage and uneconomic "pay-out" status. Proration restrictions do not encourage hasty, ill considered drilling programs. Wells are drilled to great depths with a certainty and speed that ten years ago would have been considered impossible, and at a cost barely half that formerly applying to wells of comparable depth. Directional drilling and well surveying methods permit of drilling a well to reach a desired objective whether vertically below the starting point or not.

A notable advance has been made in well completion methods and in sampling and testing prospective producing formations during the course of drilling wells to determine their productive capacity. Mechanical coring devices bring to the surface dependable samples of the producing formation as it exists in the earth, and laboratory inspection and analysis of such samples provide all necessary information to determine their physical character and appraise their productive capacities. Formation testers afford a ready means of securing uncontaminated samples of the fluids encountered in individual strata or productive intervals and of estimating their potential productive capacities. Electrical logging of wells provides records from which the character of formations exposed in the wall of the well and their fluid content may be inferred. The depths to top and bottom of each productive interval may be determined, so that perforations in liners may be placed accurately. The sources of water in wells can be determined with considerable certainty, so that the water-yielding formations can be cemented off. Highly efficient equipment has been perfected to facilitate water exclusion operations and to perforate liners with certainty and precision. Methods have been devised for completing wells that leave the walls free from detrital material and deposited clay sheaths that tend to restrict production. Well cavities are formed within the reservoir rock and filled with gravel, thus supporting the walls, preventing sand infiltration, reducing well and equipment maintenance costs, reducing downtime of production equipment for repair, and stimulating current and ultimate recovery.

When the well is completed we now have means available for accurate analysis of reservoir conditions. The temperature and pressure within the reservoir rock at the wall of the well can be determined with accuracy. Fluids entering the well may be sampled at the point of origin, even under high pressures. Laboratory studies of such samples permit of

Careful mud control using the apparatus shown for mixing and proportioning the Bentonite is an important phase of modern drilling efficiency.



Modern pumping equipment contributes to increased ultimate recovery.

estimating the physical properties of the reservoir fluids as they exist within the producing formation. By this means it is possible to determine essential factors, such as the amount of gas in solution in the oil, its saturation pressure or bubble-point, the formation volume and shrinkage ratio of the oil and the amount of connate water present in the pore spaces of the reservoir rock. Knowledge of these factors, and the percentage porosity or available storage space for fluids in the reservoir rock, enable one to compute the quantity of oil and gas present.

During the period of production, which may extend over many years, we may now intelligently prescribe well operation methods that will utilize nature's forces most effectively and result in the maximum possible production of drainable oil. Much depends upon proper pressure control at all times, maintenance of appropriate fluid level sand suitable rates of production. For a given set of conditions, operative at a particular time, there is a certain rate of production for a well, which, if maintained, will enable it to produce most efficiently. Proper production control contemplates determination and maintenance of this optimum rate for each well. Operators have learned the importance of proper maintenance of wells and well equipment and the necessity of utilizing the most efficient lifting methods at various periods in the productive lives of the wells.

When nature's expulsive forces have been fully utilized oil producers have developed means of creating and applying artificially developed expulsive forces within the reservoir rock to continue production beyond the time when natural drainage ceases. By vacuum - pumping, gas - injection, water-flooding, drainage through mine openings, and other secondary methods of recovery the ultimate production of oil from a reservoir may be materially increased. The pressure maintenance method, which involves injecting compressed gas into the reservoir rock as the oil is withdrawn, is an efficient and popular method of field exploitation that assures a high degree of production efficiency. The gas-drive and water-flooding methods of exploitation are also effective in securing additional oil from partially depleted fields. Most operators today are familiar with these recovery methods and they are being widely used in the petroleum industry where they are economic and conditions seem suitable.

UNRECOVERABLE OIL

While notable improvements have been made in oil production technique during recent years, it must be confessed that we still leave behind in the reservoir rock a large percentage of the oil originally stored there by nature. This is no criticism of the oil producer if he is using the most efficient methods of recovery yet developed. It merely means that no recovery methods yet discovered, that may be economically employed with present day oil prices, are effective in producing more than a part of the oil actually present in the reservoir rocks.

This is not surprising when we consider the conditions attending storage of oil in nature's reservoirs. The oil is distributed through the minute pore spaces of porous rocks in a way that makes recovery of all of the oil impossible by any method short of actual mining and disintegration of the reservoir rock and treatment of it by some process involving solution or washing. If we would recover it through wells from the reservoir rock in place the oil must drain to the wells through long, slender, tortuous channels with many constrictions that interpose great resistance to movement of fluids. The minute pore openings of the reservoir rock exercise a capillary attraction on the reservoir liquids that prevents a large part of the oil from draining freely. The rock walls of these pore spaces present, in the aggregate, enormous surfaces to contact with the oil, and these surfaces remain wet with a film of oil after all free-draining fluids have been removed. The adhesive force existing between the mineral surfaces and the oil, and capillary retention of oil within the rock pores, are thus responsible for failure to produce a part of the oil actually present in the reservoir rock. No economic method of recovery yet discovered, that may be applied through wells, is effective in liberating oil so retained within the reservoir rock. Eventually, some process involving flooding with water or chemical reagents capable of releasing this oil may be developed, but liquid displacement methods are thus far employed in primitive ways that do not permit of sufficiently accurate control to assure complete recovery.

In any discussion of oil recovery we must distinguish between total oil content of the reservoir rock and recoverable oil content. By the latter term is meant that part of the total oil content that is recoverable by any practical economic process when applied in field operations. All available data indicate that with the methods of oil recovery feasible today less than half of the actual oil content of the reservoir rock is recoverable, often much less than this.

The writer and his associates have conducted numerous laboratory tests involving drainage of crude petroleum from oil saturated sands under a wide variety of conditions. In most instances, less than a third of the oil has been recovered. While production of as much as 80 percent of the total oil content is sometimes obtained by water flooding under ideal conditions, it is believed that such conditions seldom if ever are realized in nature. Evidence from the field also confirms these conclusions. Cores taken in some of the Pennsylvania fields, in territory subjected to drainage over a period of many years, in which the wells had practically ceased to be commercially productive, have indicated recoveries of less than 35 percent of the original oil content. There is necessarily some question of the validity of recovery estimates of this character when applied to core data because of the unknown amount of connate water that may have been present in the reservoir rock. However, an instance is reported in the Pechelbronn Field in Alsace in which it was shown without question that the recovery by ordinary methods of flowing and pumping through wells during the economic life of the field yielded only one-sixth of the oil actually present. Here there was no connate water to render the result uncertain.

The question of the percentage of oil recoverable under different field conditions and by different methods of exploitation is one upon which petroleum production technologists are still not agreed. It may conceivably vary over a wide range. This is a

factor that enters into reserve estimates, appraisals of oil properties, proration programs, and other engineering problems; and there is need for a more precise means of evaluating it. A committee of the American Petroleum Institute is now studying this question, and though it is not a new problem it is probable that out of this study may come a better understanding than we now possess of the relation of recoverable oil to total oil content of a reservoir.

PROTECTING RESERVES

Oil left in the ground unrecoverable by present-day methods may, in future, be partially recoverable by improved methods of field exploitation. With this in prospect it is highly important that these reserves be protected against water incursion and widespread dissemination through barren formations to which they may gain access unless the wells are suitably cased and the reservoir fluids confined by appropriate means. This is true conservation, and in most states where oil is produced and conservation laws are in effect state agencies are doing everything possible to protect against loss and wastage. Estimates indicate that we have a very large stake in the unrecoverable reserves in present known fields of the United States. Since the beginning of the industry in the United States about 22,500,000,000 bbl. of oil have been produced. If the yield has been, say, 25 percent of the original oil content of the fields exploited, it follows that 67,500,000,000 bbl. of oil must still be in the ground in these fields. If recovery has been only 15 percent as many petroleum technologists believe, more than 110,000,000,000 bbl. still remain. Of course, not all of this reserve is recoverable. Perhaps the best we might hope for is half or two-thirds of it; but, in any case, it is a substantial reserve; no doubt greater than the 18,000,000,000 bbl. reserve estimated as being recoverable from present known fields by present day methods.

California is an important testing ground for improvements in equipment.

© Triangle

© Triangle

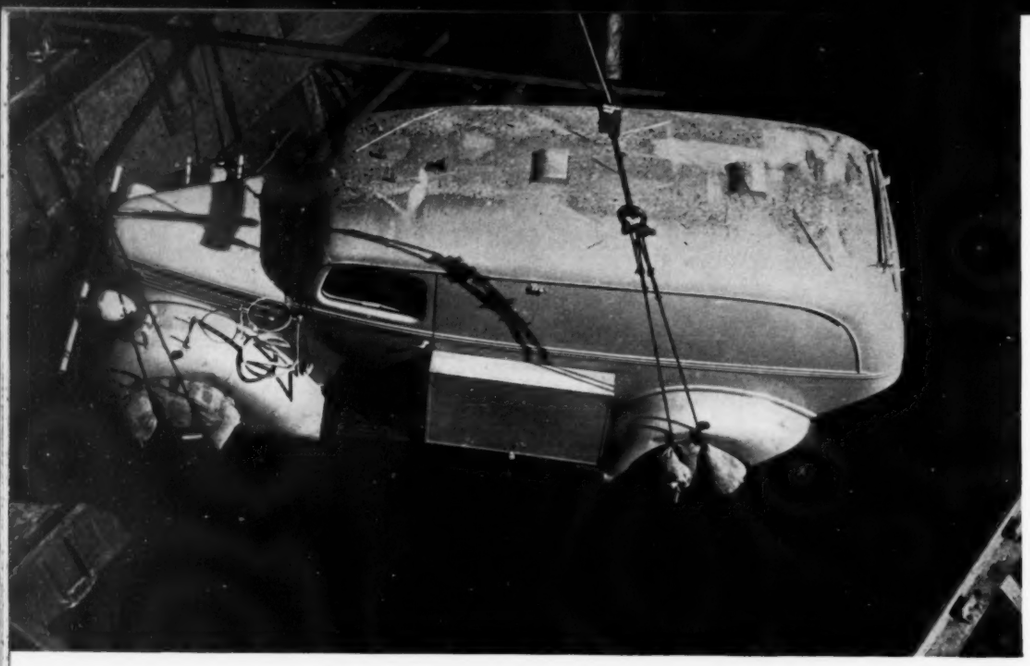
Careful examination of cores has been used as a guide in estimating total oil in the reservoir.

Future production from today's unrecoverable reserve is certain to be more costly than production secured by present methods. In future time, when the price structure is on a permanently higher level than it is today, we shall be able to afford the improved methods of recovery that will secure a new crop of oil from our old and partially depleted fields. It is a well understood principle among engineers and economists that the available reserve of petroleum that might be visualized for the future is a function of the price at which it can be marketed. The higher the selling prices of petroleum products, the greater the reserve.

ECONOMIC CONSIDERATIONS

Those who are critical of the oil industry's methods often overlook the underlying economic considerations that determine the methods of field exploitation employed and the efficiency realized. More wells are not drilled because if drilled they will not pay out. Wells are abandoned though still productive because they do not yield enough to return the cost of well operation. Producers are content with a certain recovery per acre because that much brings maximum profit and to produce more would reduce profits. It must be remembered that the objective of the oil producer is not necessarily to secure the maximum possible recovery from his property but rather to realize the maximum possible profit in its exploitation. The oil producer is interested not so much in conservation of oil as in conservation of capital. Thus,the interest of the state is not necessarily identical with that of the oil producer, and ideas of what is or is not wasteful in oil field operation will depend somewhat upon one's viewpoint. We regard with disfavor methods of oil field exploitation that permit quantities of natural gas to be burned in open flares just to get rid of it, until we appreciate that it may be physically or economically impossible to return it to the productive formation for storage and that it may cost more to move this gas to a possible market than it is worth in that market. Let no one be critical of another's methods until he can show how a better result might be secured without sacrifice of profit.

No one will contend that today's methods of oilfield exploitation are perfect or that all operators use the most advanced methods. Today's most efficient methods will seem wasteful a decade or two hence. Some of the best engineering skill of our time is being directed toward this problem of increasing recovery efficiency, and research is contributing much to our knowledge of production technology. Improved methods and equipment are resulting in lower unit production cost which, like added price, means increased profit and greater economically producible petroleum reserves. The trend toward more efficient recovery methods continues and will continue for many years into the future. Tomorrow's methods will always be superior to today's.



United Geophysical Company counted themselves fortunate when their truck emerged from the unloading operation in South America, pictured at left, with nothing worse than a dented rear fender.

WORLD WIDE Drilling Activities Continue in Unabated Volume.

While War Has Caused Temporary Slackening of Operations in Some Areas Increased Effort is Being Put Forth in Others — Noteworthy Developments in Near and Far East.

TAKING account of the world at large it appears from reports received during the first half year that the amount of new drilling during 1940 will be very close to the figures for the year preceding. Even in the countries overspread by war the search for oil is being carried forward with undiminished vigor except in a few areas where private companies have had to suspend operations temporarily because of difficulties in getting delivery of equipment or in maintaining financial support owing to the unavailibility of exchange. In general the governments even of belligerent nations have encouraged the continuance of exploration and have endeavored to provide the facilities necessary for this work. In several of the neutral countries increasing demand arising from the war, or anticipation of such an increase, has stimulated efforts to step up production by means of more active drilling.

Since the United States is by far the largest producer and consumer of petroleum products the extent of its drilling activity powerfully affects the total. During the five years 1935-39 the average number of wells completed yearly in the United States was 27,700. The banner year in this respect was 1937 when demand for petroleum products was rapidly expanding and when a total of slightly over 33,000 completions was recorded. In general drilling activity moves in ratio with consumption and prices though this is not invariably the case. In 1939, for example, drilling was slowed down by the widespread suspension of production during the latter half of August but the total of 27,550 new wells for the year was only about 700 below 1938.

Reports for the first half of 1940 with June partly estimated indicate a total of approximately 14,650 wells completed. This represents a gain of 18 percent over the corresponding period of 1939. While it is possible

At left above, an Argentine bridge with overtones of San Luis Rey—only entrance to one location where a United Geophysical crew had to set up. Directly above, tropical costume for a seismograph computer in Trinidad. Left, Alaskan camp near location of the Iniskin wildcat.

that a rigid application of proration in Texas and other leading producing states may slow down drilling activity slightly during the months immediately ahead present indications are that more wells will be completed in the United States during the current year than in any previous one except 1937. With drilling in other countries maintaining the pace established during the past two years it appears probable that 1940 will record a high degree of expansion in the world oil industry.

Views to the left and below show the layout of the location of Dominican Seaboard Oil Company's Quita Coraza No. 1 in the Azua province of the Dominican Republic.

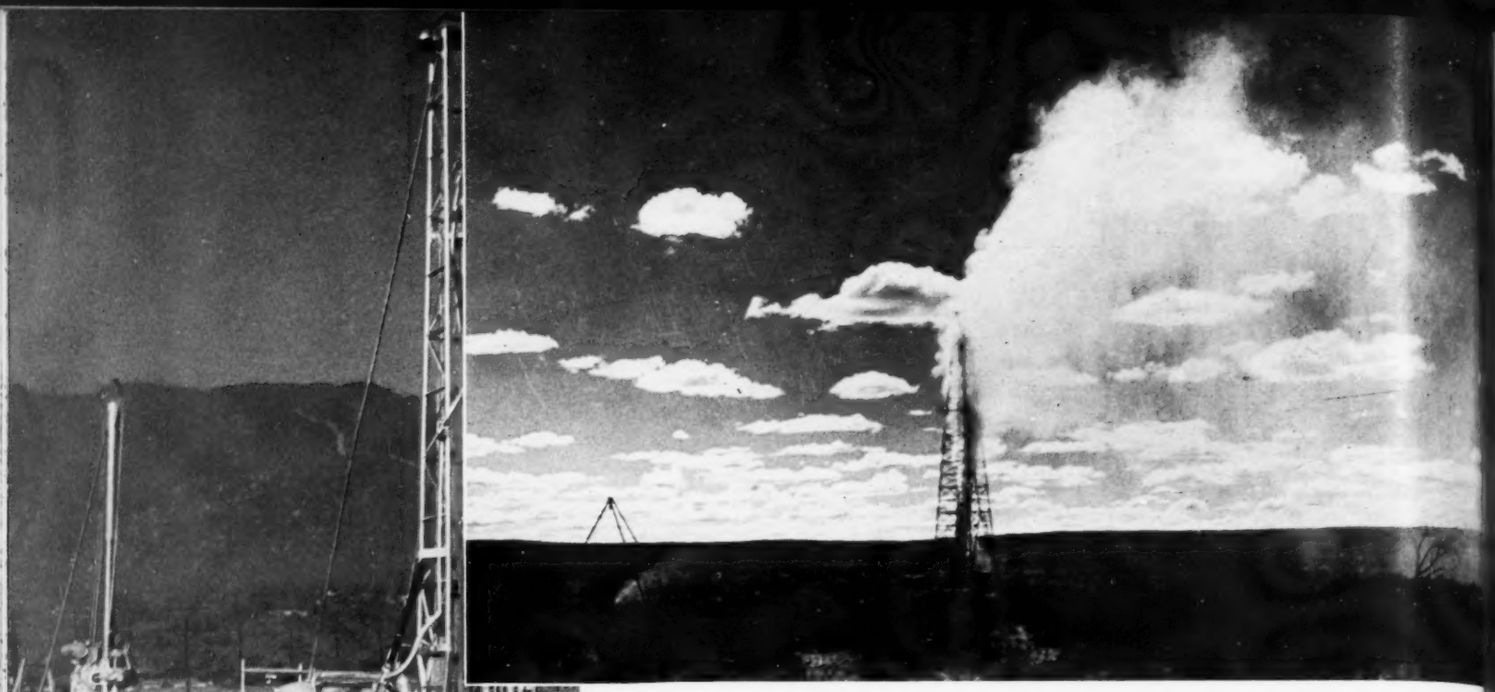
CANADA

Canada's production of oil has increased fivefold in the past four years, due to the progress of development in the Alberta fields of which Turner Valley is the most important and best known. This growth is being continued in 1940 as indicated by the fact that production for the first quarter was 18,527 bbl. daily as compared with 13,585 bbl. in the corresponding period of 1939.

At the close of 1939 there were 96 producing wells in the Turner Valley field. By March 31 the number had increased to 102. Of the six wells completed in this period four are rated among the largest producers in the Valley, and one of them, Home No. 3, at the north end of the field, has the record for production. Particular significance attaches to one of the others, Arrow, because it establishes the existence of commercial production in the area between the north and south pools in the 16-mile zone. The Conservation Board gave the well a daily allowable of 416 bbl., one of the highest in the field, and the success of the well has led to plans for further drilling both to the north and south of its location.

Several test wells looking to the extension of Alberta fields are being put down. One of these is located ten miles north of the Turner Valley field near the Scarcee Indian reserve. Another drilling site selected by Ram River Oils is intended to test the Devonian formation at Prairie Creek, 75 miles north of Innisfail.

One of the spectacular events of the current season took place on March 6 when Princess



No. 1 of Standard Oil Co. of British Colombia at Steveville, about 100 miles west of Calgary, went out of control, blowing out a heavy drill collar and connections, bringing down the derrick and strewing the ground with a mass of wreckage. It was estimated by engineers that the flow of gas was 65,000,000 cu. ft. With this huge gasser under control the drilling of another test well in the vicinity is under consideration.

Since the Alberta fields have outgrown the local market and the cost of rail transportation over the 1,200 miles separating them from a deep water terminal on the Great Lakes makes it impossible to compete in Eastern Canada, the wells are operating under strict proration. Drilling activities continue unabated, however, in the hope of raising production to a point that will justify the construction of a pipe line eastward to the Great Lakes or across the Rockies to the Pacific Coast.

ALASKA

Although politically a part of the United States Alaska is so far separated geographically that from the point of view of oil exploration it may be treated independently. As described in WORLD PETROLEUM last year two tests were at that time being conducted in Alaska. One of these was a joint venture of Standard Oil Company of California, Tide Water Associated and Union Oil Co. who were engaged in putting down a test in Salmon Creek Valley, near Kanatak, which has now been abandoned. The other was a well drilling by Iniskin Oil Company on the Iniskin-Chinitna peninsula where work has been proceding for the past four summers.

This work is now temporarily suspended, not for lack of favorable oil showings but because all Alaskan permits expired December 31, 1939, and to continue operations it was necessary to obtain a new lease.

This lease has now been granted and drilling will be resumed next summer. As the working season is short, extending only from the middle of May to the middle of October, and as the site is difficult of access even in good weather progress necessarily is slow. On account of high tides which range to 32 feet supplies have to be debarked six miles from the shore of Chinitna Bay.

The drill is now down 8,775 ft. Favorable showings of gas and oil logged in a test from 5,600 to 8,775 feet. The oil is paraffine base, 45 gravity, 50 percent gasoline, and the company has been encouraged to go on and if possible bring in production in commercial quantity.

To date, the well has cost $840,000, or nearly $1,000 per foot. Another summer's drilling will probably be decisive one way or the other, because the hole has narrowed down to 4 ⅞ inches at the bottom, and will hardly permit going more than another 1,000 feet. The completion of a real producing well would have great significance in Alaska, which is a substantial consumer of petroleum products, and offers a market for a sizeable oil industry.

MEXICO

During the past two years, following the seizure of privately owned oil properties by the government of Mexico, drilling has been almost at a standstill in that country. Prior to the seizure development of the rich Poza Rica field, largely owned by Shell interests, had added greatly to Mexico's productive resources. With diminished export sales following confiscation it was possible to meet current demand without additional exploration. Agitation for further drilling has been going on for the past year among representatives of the workers, however, and it was pointed out that unless such work was resumed production soon would enter a more serious decline.

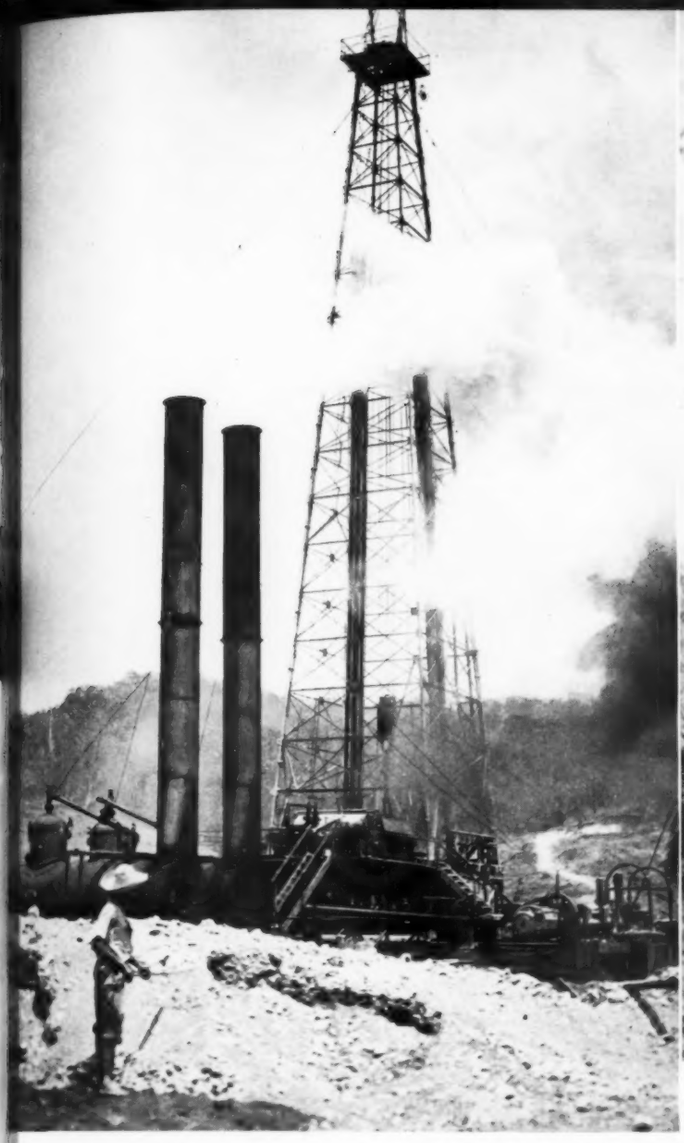
Early in the year President Cardenas promised representatives of the oil workers' unions that an active campaign of drilling would be put under way this year. Shortly thereafter it was announced by the Minister of Finance that the government was spending $600,000 for new drilling equipment, that 11 wells with an expected production of 5,000 bbl. each were being drilled in proven areas and that nine more were to be started in June. This apparently constitutes the government program for the year.

In Central America a subsidiary of Shell has been engaged in a geophysical survey of a large area in Gautemala following an extensive aerial photographic survey. So far as reported no steps have been taken toward test drilling as yet. Elsewhere in Central America some preliminary geological reconnaissance is taking place. It was reported several months ago that an exploration permit covering British Honduras had been granted but no work has been done under it thus far.

WEST INDIES

One of the most tantalizing areas that exploring oil men have encountered is Cuba. Geologists and geophysicists have located structures that afford every promise of production. Practically every well put down in the districts selected for test has encountered oil showings but the first large scale producer has yet to be brought in. A number of wells have found small production from relatively shallow depths. One such was recently reported from Havana province but the prolific fields in the existence of which many oil men still believe have not been located.

The most systematic and scientific exploratory work yet conducted in Cuba is now being carried on. The chief factors in this search are the Atlantic Refining Company and Shell-Mex de Cuba although several other companies hold small areas in which they propose to make tests. Both Shell and Atlantic



Reading from left to right, United Geophysical's smallest and largest drills in Brazil, the smaller being capable (and accustomed) to hand transportation, the larger being capable of 100 ft. hole in hard formation: the next picture represents an attempt by a United Geophysical seismograph driller to tap shallow sand in Argentina (tripod) to control the wild well at right. Drilling rig and boilers belong to Dominican Seaboard Oil Co. as does the drum of Dominican Republic crude in the last picture.

have extensive holdings in Pinar del Rio and Havana provinces in the western part of the island and in Matanzas and Santa Clara, further east. Extensive geophysical surveys have been made in the Havana area and Atlantic has a seismograph crew at work in Pinar del Rio. Seismograph and gravity meter parties operating in Matanzas recently returned to the United States to await the conclusion of the rainy season before resuming operations.

The first wildcat put down by Atlantic Refining Company was Puntilla 1, near Remedios in Santa Clara province. The well encountered showings of oil at 2,300 ft. but ran into a cavernous limestone formation. A second location was selected two miles north of Colon in Matanzas province. This was drilled to 6,100 ft. passing through shales, limestone, deep sands and volcanic ash, the latter terminating hopes of production.

At Recreo, Matanzas, a well drilled to 4,104 ft. made good showings of gas and oil from the 900 ft. level down. At one point a six inch layer of asphalt was penetrated showing that oil had existed there but that its lighter elements had escaped. Lack of porosity and permeability in the lower structure caused the well to be abandoned. A fourth well is now drilling near Angelito, about two miles from Recreo.

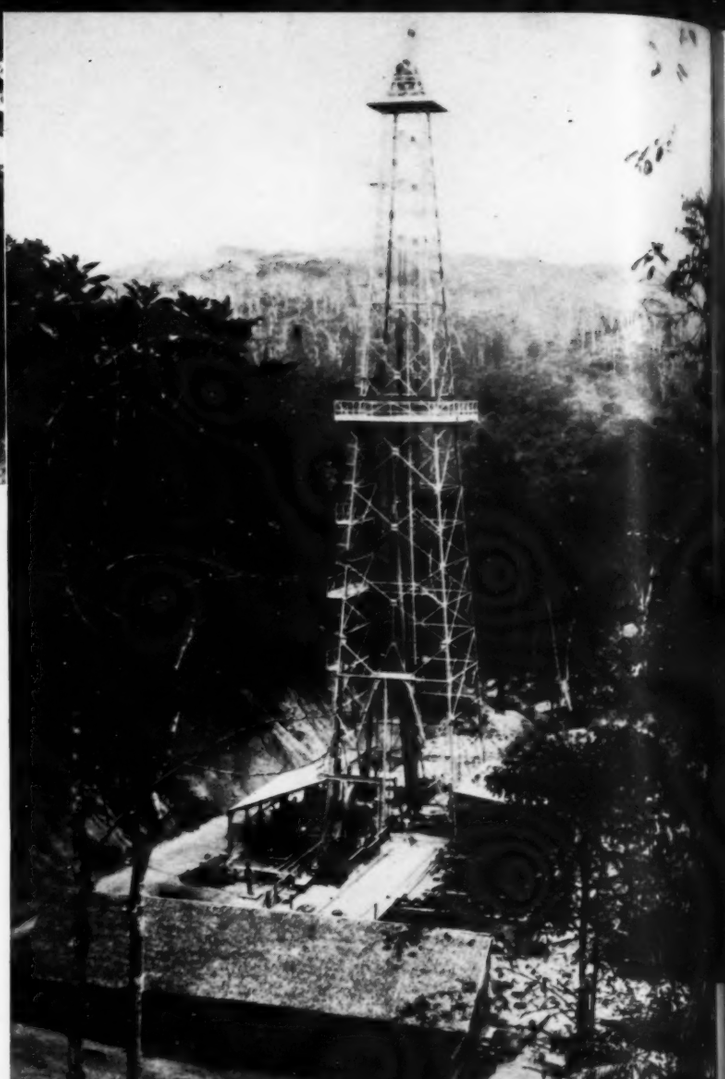
The present program of the company calls for the drilling of slim holes for shallow production to provide fuel for field operations and also for gaining more knowledge as to the geological columns for use in deep drilling later. Seismograph and gravity meter surveys are to be extended to cover the north coastal plain in Matanzas and Santa Clara which covers a great sedimentary basin extending to an undetermined distance underneath coastal waters.

Shell has drilled two deep holes in Havana province. The first of these was drilled to 5,200 ft. and encountered showings of oil on the way but ended in impervious rock. The second went to 10,034 ft. with like results. Shell also has put down a number of core holes south of Colon in Matanzas province but has not attempted to sink a deep well in this area. Early in the year Shell's operations were suspended temporarily but are to be resumed later.

Cuba has one remarkable productive field in which drilling operations continue steadily This is the famous Motembo district where an almost pure gasoline is obtained from shallow wells. While production per well ranges from one to five barrels daily the high price obtained for the oil and the low cost of drilling makes the operation profitable. At the present time some eighteen companies and forty rigs are operating in this area.

To the eastward of Cuba lie Haiti and the Dominican Republic, occupying the single island which Columbus named Hispaniola. Haiti comprises the western third of the island and the Dominican Republic or San Domingo as it is commonly referred to occupies the eastern two thirds. Mountain ranges enclose deep geosynclinal valleys and there are long narrow anticlines with numerous faults which suggest the possibility of oil deposits.

Oil seepages exist in San Domingo and in years past several shallow wells have been drilled in the vicinity of these. At the present time a systematic search is being conducted by the Seaboard Dominican Oil Company.



In Trinidad crews of United Geophysical Co. found conditions that permitted work to be carried on about as easily as in the United States, as pictured above. On the right is shown a drilling rig of N.P.P.M. (California Standard and The Texas Co.) towering above the office and warehouse in foreground in the East Indies. At the bottom of the page on the left is Dominican Seaboard's El Magote No. 1 drilling at 340 ft. in February this year.

Surveys have disclosed the existence of five basins with well closed anticlines and test wells have been drilled in two of these.

Moleno 1, the first of these tests, found shallow production between 400 and 600 ft. The bore continued to 1,000 ft. but the well then blew out from the 600 ft. level. It was then plugged back and completed at 600 ft. in July 1939. At its completion the well produced 600 bbl. per day of 19 gravity oil with some water. Though yielding practically no gasoline the oil has high lubricating value. Production has since declined but the well has produced some 17,000 bbl. which has been used as fuel in conducting further operations.

Moleno 1A, drilled to 3,200 ft. in this same area, encountered high porosity and a heavy flow of salt water at 3,000 ft. and was abandoned.

The next test was made on the Quita Corozo structure, some twenty miles west of the initial well. It was carried to 3,200 ft. without showings. A fourth hole, on El Magote structure, went to 7,505 ft. with like results.

These structures are all in the Azua basin. There are a number of others that justify exploration. For the present further deep drilling has been suspended pending further surveys but the rig is being kept and tests will be resumed when more complete geophysical information has been assembled. Meanwhile a light rig will be employed to test the area for shallow production.

In Haiti Atlantic Refining Company holds a concession covering over 2,000,000 acres but only preliminary work has been done thus far. Recently an aerial photo survey was made by Atlantic Refining and Seaboard Dominican covering the territory of the two companies on both sides of the international boundary. At the present time Atlantic has a geological renaissance party at work in Haiti but several months probably will elapse before drilling can begin.

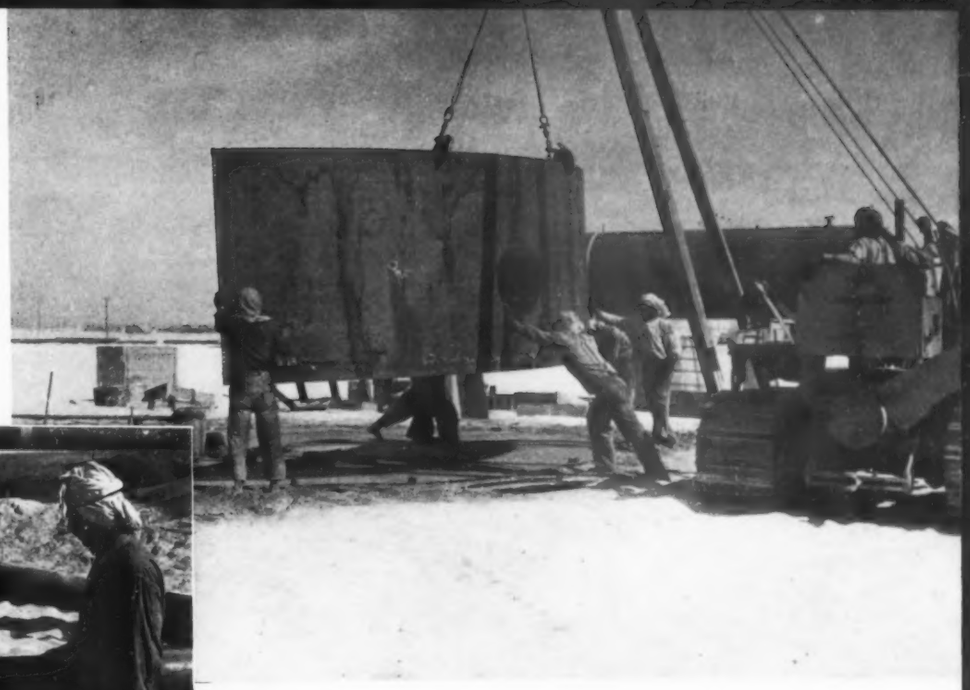
While there has been for many years a small production in Barbados the only other part of the West Indies seriously considered as an oil producer is Trinidad. Geologically Trinidad is part of the continent of South America which is treated in a separate article.

Oil search in Europe is discussed on other pages of this issue. It is important not so much because of the size of the fields developed as because of the fact that Europe while a large consumer of petroleum products is a small producer and is compelled to import 80 percent of its supply. Under these circumstances any addition to local production assumes special significance to the country concerned.

South of the Mediterranean Egypt has been the scene of active drilling during the past year. Some of this has been devoted to extension of the Ras Gharib field which first entered production in 1938. Part of it has consisted of further test drilling in adjacent areas and in the Sinai peninsula. Most of the large international companies hold exploration permits in Egypt and the whole area containing potentialities of oil production will be carefully tested as time goes on. Because of the involvement of northern Africa in the war following Italy's entry into the conflict no late reports of drilling progress in Egypt have been received.

NEAR EAST

Developments in the Near East during the past year have served to strengthen the belief established by earlier progress that this historic area is destined to occupy a leading place in world oil supply for many years to come. Exploratory drilling has led to the extension of existing fields and the discovery of new ones in widely separated districts, supporting the opinion that this south-



Constructing tanks and tank lines at Ras Tanura in Saudi Arabia, a part of the extensive operations of California Arabian Standard Oil Co.

western corner of Asia contains oil deposits of an extent and richness unsuspected until within the past few years.

Among the most noteworthy of these recent developments are those that have taken place in Saudi Arabia. Following its determination of the permanent character of the Dharan field through discovery of the Arab zone and the encouraging results of surveys elsewhere the California Arabian Standard Oil Company applied for and received a great enlargment of its original concession which now covers the whole northern, eastern and southern central portions of Saudi Arabia, embracing an area of more than 250,000 sq. mi. While the greater part of this vast territory has not yet been subjected even to preliminary surveys the geological and geophysical studies made at various points indicate the existence of favorable structures underlying large areas and hold the promise that as time goes on Saudi Arabia will possess not one but many highly productive fields.

The first drilling on Damman dome, centre of the Dharan field, was done in 1936 and the first well was brought in from 2,175 ft. Five more wells were put down to similar depths and all showed production. Initial flows were not large, however, and quickly began to fall off, while the quality of the oil was inferior.

Taking a leaf from its experience at Bahrein the company decided to make deeper tests.

In 1938 the first of these tests developed a large flow of 35 gravity oil from the so-called Arab zone at approximately 4,200 ft. Activities were immediately directed to the deepening of the other wells previously drilled to the 2,000 ft. zone and the sinking of additional deeper bores. As a result 15 wells have now been completed in this field. Because of inadequate transportation facilities production had to be held down but in 1939 the output was just under 4,000,000 bbl. and is capable of being greatly enlarged from this field alone.

To provide for handling the oil a 40-mile pipe line was built from the field to Ras Tanura on the coast of the Persian Gulf where a marine terminal was constructed last year. A submarine extension enabled oil to be loaded into ocean tankers. A large part of the oil, however, was transferred to the Bahrein refinery for processing.

Since this plant has been operating at full capacity from the date of its completion the company has now began work on a new refinery at Ras Tanura which will be completed during the coming year.

One of the sites selected by the geologists of California Arabian Standard for early test, following the discoveries at Dharan, was at Abu Hadriya, approximately 100 miles to the northwest. Drilling of this test which was located on a large dome was followed with close attention by oil men interested in the Near East because it was expected that if successful it would yield important information as to the extent and direction of productive zones in this entire region.

After hope had been deferred many times Abu Hadriya was brought in last April from 10,220 ft. Company officials are satisfied that it marks the beginning of another important field which may call for the construction of a second marine terminal at Manifa, about 20 miles distant on the Persian Gulf.

A third point at which exploratory drilling has been going on in Saudi Arabia is a dome 120 miles west of the Dharan field. This well is known as Ma'agala No. 1 and the latest report is that drilling is in suspension.

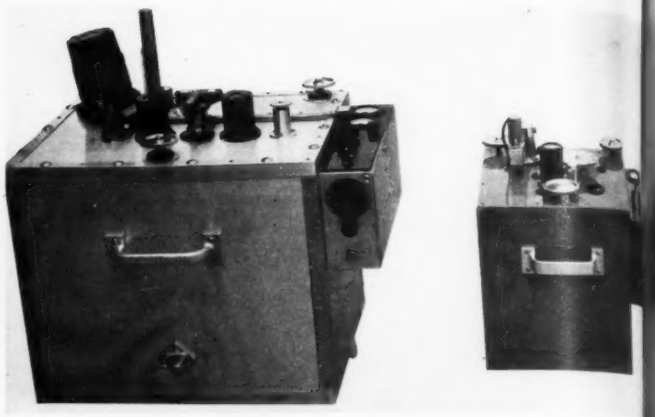
While these developments have focussed attention on the mainland of the Arabian peninsula the field at Bahrein, just off the coast in the Persian Gulf, has continued its

(Continued on page 94)

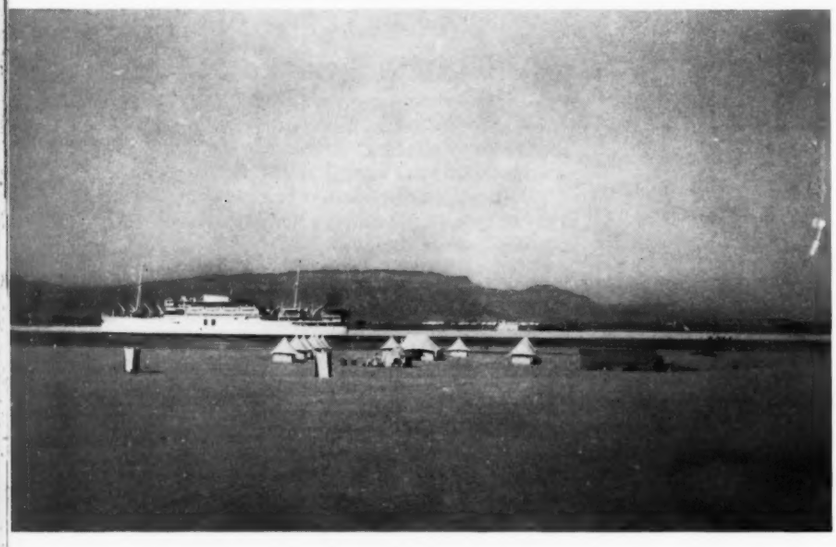
Iniskin wildcat dominating the bleak Alaskan landscape after the winter shut-down as it looks to the crew arriving in the spring to resume operations.

Gravimeter In World Wide EXPLORATION

By L. M. Mott-Smith



The value of the gravity method of oil exploration has been recognized for many years. Until the latter part of 1935 such gravity surveys were made almost entirely with the torsion-balance, as this was the only type of instrument for measuring gravity capable of sufficient accuracy. At the present time the gravimeter has for all practical purposes replaced the torsion-balance and, to a considerable extent, use of the seismograph for rapid reconnaissance.



Top: comparing the old and new Mott-Smith gravimeters with the original model on the left and the latest model on the right. Left above, a gravimeter camp on the banks of the Suez in Egypt and right, moving camp in the desert. To the left, Bedouin watering camels at the camp well in Arabia and below, an Arab soldier at the Mott-Smith camp.

The purpose of all geophysical work is to determine as exactly as possible the geologic conditions beneath the surface of the ground. In exploration for petroleum, geologists are interested principally in anticlinal or domal traps, faulting producing favorable conditions for accumulation of oil, and the like. Generally, the presence of these types of geologic structures can be inferred by examination of a gravity map of the area in question. The certainty with which such inferences can be made unfortunately varies markedly from one geologic province to another. A certain amount of information of value can, however, be obtained from gravity maps in practically every region. In favorable areas the correlation between subsurface conditions and the gravity values indicated on the map is so good that the presence of a condition favorable to the accumulation of oil can be inferred with considerable certainty.

In less favorable areas such as are encountered frequently, the gravimeter is used for

Above, a gravimeter camp in Colombia, and right, moving camp under equally difficult but entirely different conditions than those pictured opposite: Extreme right, starting out for a day's work in Colombia.

rapid preliminary reconnaissance, later to be followed by some other slower method giving more detailed information. Both seismic and core-drilling methods have been used for this purpose, the choice depending upon which is the more suitable for the area in question. Employing this technique, the work of seismograph or core-drill is restricted to localized areas that have been indicated as favorable by the gravity reconnaissance. One advantage is that the over-all cost of exploring an area is considerably less than it would be if the entire area were covered in detail with the seismograph or core-drill. Another advantage, which is particularly important in areas where several oil companies are competing with each other, is that of speed. Although the method may fail to find some minor structures which are too small to be indicated by the gravity work, it allows the majority of structures to be located in much less time than that required to cover the whole region with the slower methods.

It is reported that one of the outstanding geophysical successes was achieved by the organization which first used this technique. It led to the discovery of several valuable oil fields in an area of the Gulf Coast where perhaps ten other strong companies were carrying on intensive exploration programs with little success.

In areas favorable to gravity work the gravimeter alone may be used to make test well locations. In these areas the work is done more carefully. After a preliminary large-scale map has been made, the interesting spots are reworked in detail. Here the stations are placed only perhaps 1,000 ft. apart, where in the initial work the spacing may have been 5,000 ft. In Egypt, where the fields have been found above buried granite ridges which can be located by the gravimeter with considerable accuracy, test-wells are being drilled upon gravity data entirely. The Gulf Coast of Texas and Louisiana is another favorable region where gravity work alone has located numerous fields. This work was done before the development of gravimeters and was carried out with torsion-balances. The maps, however, give the same type of information and there is no doubt that if gravimeters had been available they could have been used and the same discoveries made. In this connection it has been suggested that the coastal plains of China may very well be similar geologically to our Gulf Coast. If and when the exploration of this region becomes feasible, we may see a rapid increase in the world's petroleum reserves following a program of exploration,

Left, transportation of equipment presents great difficulties as in this Colombian stream: Right, a surveyor with a Mott-Smith gravimeter party locating a station in the Colombian jungle.

Off the Cayos of Cuba this 17-foot tower, controlled by the barge from which it is suspended, is used in water, up to a depth of 15 ft. The tower, flat-topped, serves both gravimeter operator and surveyors. The gravimeter can be read on the tower even in quite rough water. Surveyors obtain the elevation from sea level and the location by sighting from the station to three triangulation points on the shore. Between stations the tower is raised by a winch and the barge towed by another boat.

the spear-head of which will be the gravimeter.

During the past two years considerable improvement has been made in gravimeter instruments. With the new equipment the accuracy of the surveys has been increased and observations can be made much more rapidly. The accuracy of modern instruments is so high that further improvement in accuracy would be of little value. With early equipment and under average conditions it was possible to obtain four to five hundred points per month. Today it is often possible to obtain 1,500 observations per month. Moreover, the new instruments are much more reliable. With early equipment faults requiring return to the laboratory for repairs were a frequent occurrence. Present instruments can be expected to remain in proper operating condition without expert attention indefinitely. To facilitate transportation under difficult conditions the present trend is toward lighter and smaller instruments. The Humble Oil & Refining Company is reported to be using an instrument weighing only 35 lbs., and the Mott-Smith Corp. has recently brought out an instrument weighing 50 lbs. This is to be compared with weights of 70 to 150 lbs. for the earlier types.

An interesting new development is the construction by Gulf Oil Corporation of a gravimeter which can be submerged in water. This instrument was developed to survey prospective areas in shallow waters along the coast-lines or in lakes, such for example as in the Gulf of Mexico along the coast of Texas and Louisiana.

Statistics on the scope of geophysical exploration are difficult to obtain because this information is considered confidential by many companies and would in any case have to be gathered from numerous sources. The writer has therefore limited himself to presenting information of the operations of his own company which, however, represent about one-fourth of all gravimeter work carried out to date. This information is presented in tabular form below:

United States of America (Gulf Coast, Mid Continent and Illinois Basin areas)	262	September, 1935
Egypt (Red Sea Coastal area)	80	April, 1938
Western Cuba	19	November, 1938
Colombia (Magdalena Valley)	39	January, 1939

Gravimeter camp in the Llano, Venezuela: tarpaulins over tents minimize the heat of the intense tropical sun.

Eastern Venezuela (Broad plains region between Orinoco River and the Coastal mountains)	40	January, 1939
Saudi Arabia (Coast of Persian Gulf)	12	February, 1939
Iraq (Norther part west of Euphrates River)	15	March, 1939
Canada (Southern Ontario)	8	June, 1939
Argentina (Foothills of the Andes in vicinity of Mendoza)	4	March, 1940

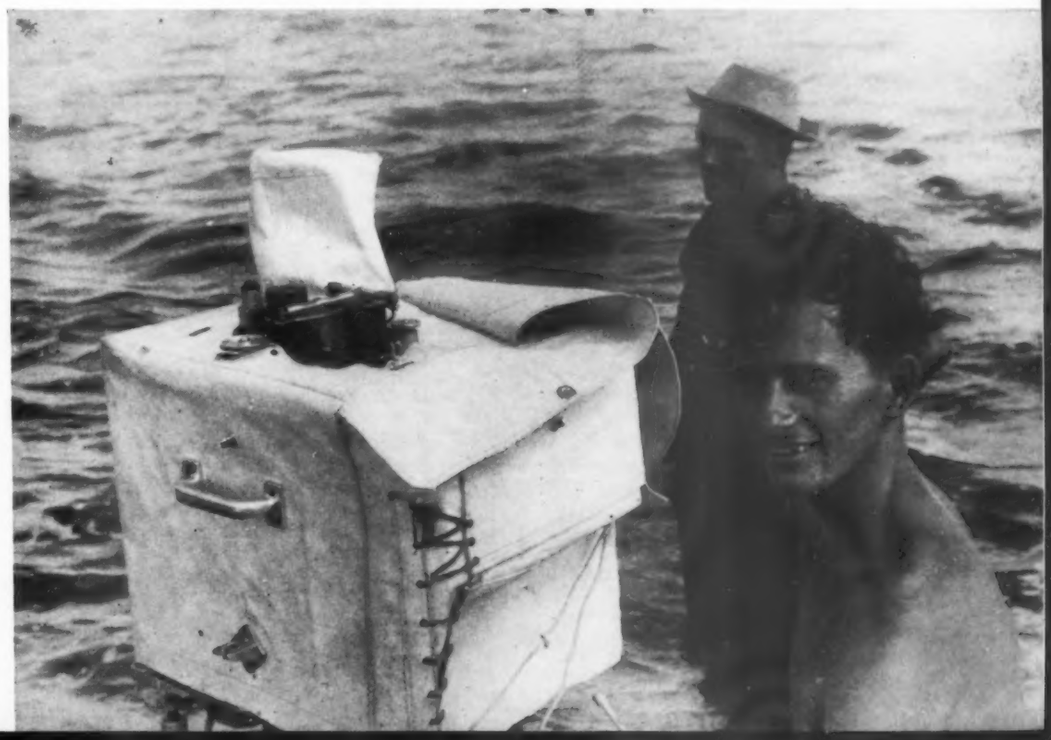
Other companies, in addition to making gravimeter surveys in some of these countries have been using this method of exploration in many of the countries of Europe, in New Zealand, the East Indies, Ecuador, and in Peru.

Above, railroad set-up in the Cuban jungle. In such areas there are frequently no other roads than the tracks shown here, so motor cars are put on the tracks and used to transport both the gravimeter crew and the surveyors. Left, Cuban dry-weather road. Such roads as this are entirely impassible during the rainy season, five to six months a year. Below, low water set-up off the Cayos of Cuba. The canvas cover for the gravimeter is in case of rain or rough sea. In water as shallow as this the meter is brought by rowboat from the larger boat.

A typical gravimeter party working in the United States consists of one gravimeter, a truck to transport it and the following personnel: party chief, whose duties are to supervise and plan the work of the party, compute the results, and construct the maps; a gravimeter operator who reads the instrument in the field; an assistant operator who drives the truck and helps the operator set up the instrument; and two to four land surveying crews each composed of one surveyor and one rodman whose duties are to locate and obtain the elevation of each station. In foreign work only technical men are sent out with the equipment, assistant operators, rodmen, trail cutters, etc., being obtained locally.

The entire personnel of the gravimeter party locates in the area to be surveyed. In the United States and many other countries it is possible for these men to find lodging in any convenient town or city because with good roads they can travel as much as fifty miles to work without serious waste of time. In the areas which have been worked in Arabia, Egypt, Iraq, Colombia, and Venezuela it is necessary for the personnel to live in camps.

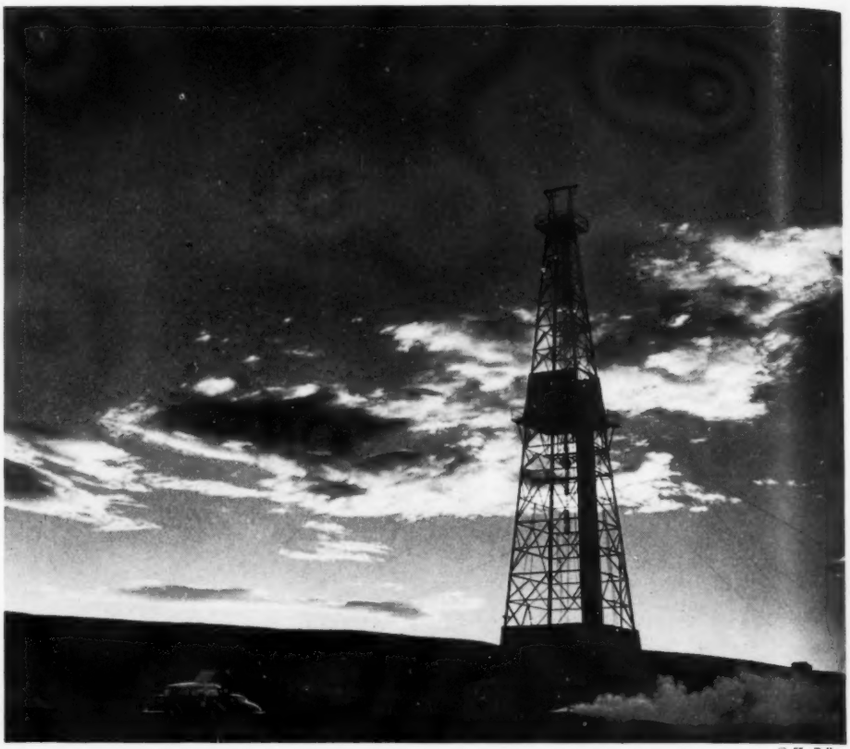
When possible, automobiles are used for transportation of instruments and camp equipment. In foreign countries automobiles are usually equipped with all-wheel-drive and over-sized tires to render them able to negotiate mud and sand. Thus equipped the cars are able to travel almost anywhere across country on the deserts of Egypt, Arabia, and Iraq and on the plains of Venezuela. About six automobiles are needed for each party. A panel truck is used to transport the gravimeter, station wagons or pickup trucks are used by the surveyors, and at least two additional automobiles are necessary for transporting supplies to the camp. In many areas, however, automobiles cannot be used. During the rainy season in Venezuela it is sometimes necessary to transport the gravimeter by hand. In practically all the areas explored in Colombia transportation has been almost entirely by hand, although some work could be done along the rivers using motor boats and canoes.



Costly Difficult Drilling Conditions Encountered in TURNER VALLEY

By Vernon Taylor
Petroleum Engineer,
Royalite Oil Co. Ltd.

Averaging But 41 Ft. Per Day, Getting as Little as Two Feet Per Bit and Subject to Excessively Cold Weather, Nevertheless An Active Drilling Campaign Continues in Canada's Turner Valley Whence Comes 96 Percent of Canada's Domestic Production.



© H. Pollard

Taking directional survey at 4:00 A.M. in Turner Valley.

THE Turner Valley gas and oil field is situated in the Province of Alberta, Canada, being 30 miles southwest of the City of Calgary and approximately 115 miles north of the United States Border. In 1939, the field produced 7,556,029 bbl. of oil or 96 percent of Canada's total oil production.

Development of the field was started in 1913 when a well was started near a gas seepage and although small quantities of light crude oil were encountered in beds of Upper Cretaceous Age, the Great War stopped any great activity. The first large producer was completed in October 1924 when the Royalite No. 4 well reached a depth of 3,740 ft., being 290 ft. in the Palaeozoic limestone, and obtained an initial flow of 600 bbl. of 72 deg. A. P. I. gravity naphtha and 20,000,000 cu. ft. of gas per day. From 1924 to 1936, 109 wells were completed as naphtha producers with initial production ranging from 50 bbl. to 800 bbl. per day. These were all high gas/oil ratio wells, ranging initially from 35,000 to 100,000 cu. ft. per bbl. Recent data have shown that these wells were drilled in the gas cap of a large anticlinal structure in which the crude oil was found on the west flank.

In June 1936, the Turner Valley Royalties well was completed as the first large producer of crude oil in Turner Valley with initial production of 850 bbl. of 44 deg. A.P.I. gravity oil and 2,000,000 cu. ft. of gas per day. The well was drilled to a depth of 6,828 ft. and as it was 350 ft. deeper structurally than any other well in the field, it demonstrated the existence of crude oil along the west flank of the structure. Since that time, an active drilling campaign has been carried on along the west flank. The large part of this development has taken place in the south part of the structure, but in recent months the north and central parts have enjoyed more prominence. The recent completion of Arrow No. 1 in the central part of the field, as the present largest producer in the field, should add impetus to the activity in this section.

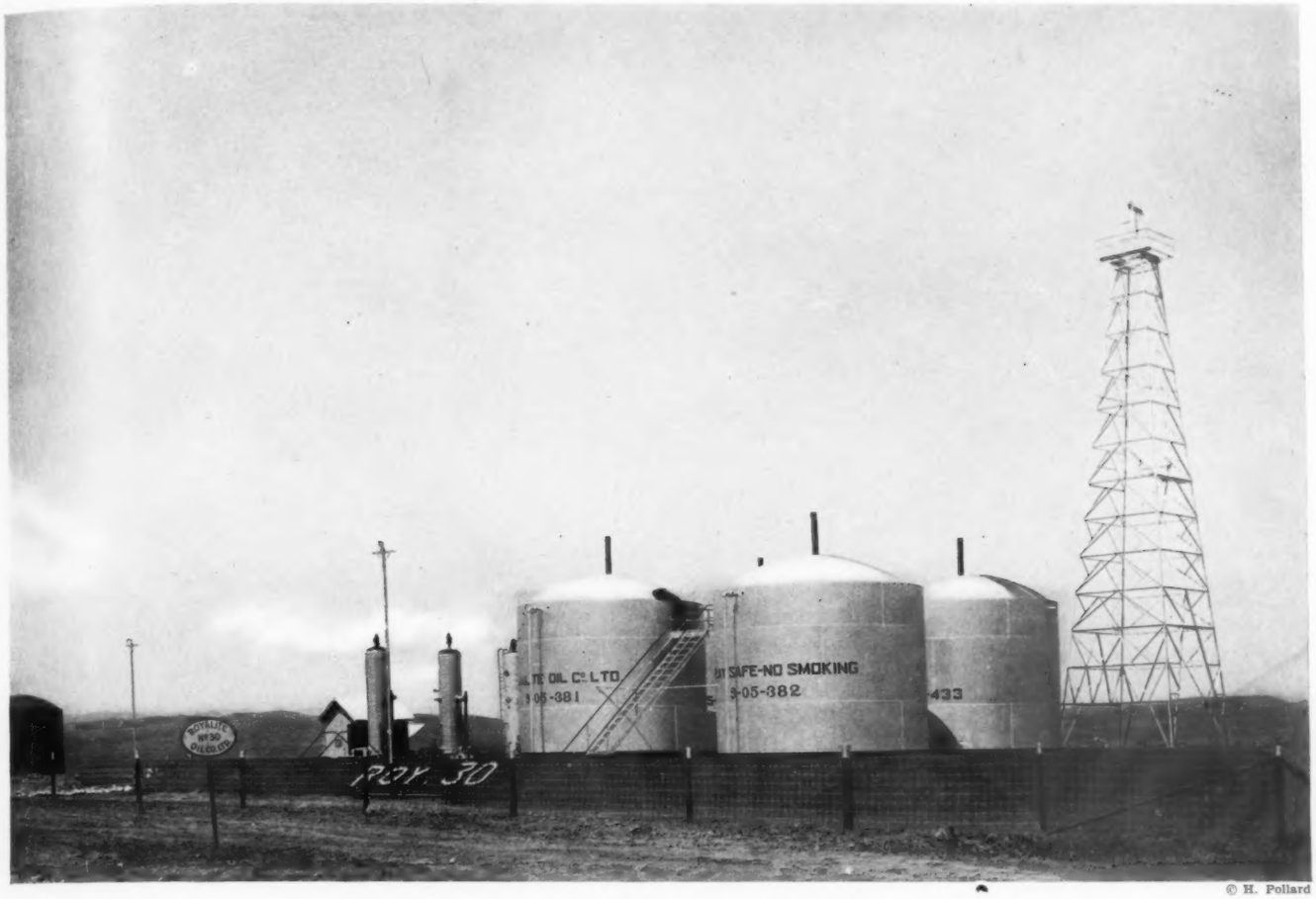
STRUCTURE

The structure is a highly faulted, closely folded anticline situated on the eastern edge of the foothills belt about 20 miles from the front range of the Rocky Mountains. East of the structure, the beds dip gently into the Alberta syncline and the surface trace of the trough lies some two or three miles east. The structure is underlain by a major overthrust fault, and the east flank may be the result of drag-folding. The eastern edge of the productive limestone is sharply defined by this fault, the subsurface trace of which has been accurately delineated by several wells which have drilled through the fault plane.

The north and south limits of the field have not yet been ascertained definitely but the total length of the productive area, to date, is nearly 18 miles. During 1939, the position of the oil-water contact was definitely established by the Royal Canadian No. 3 well in Lsd 12 of Sec. 29 Twp. 18 Range 2, West of the 5th, which drilled to a depth of 8,667 ft. or 4,377 ft. below sea level. The producing zone was encountered at 8,550 ft. to 8,660 ft. and the well had an initial production of approximately 2,000 bbl. per day without any water. Within two months the well had started producing salt water in appreciable quantities. Thus, the position of the water in this area is at approximately 4,360 ft. below sea level.

The top of the producing zone in the shallowest gas well on the structure has an elevation of 455 ft. above sea level. The vertical range of production on the structure is therefore remarkable, being 4,840 ft., with the gas cap occupying 2,500 ft. at the top.

The present area of the gas cap is approximately 8,100 acres, while the potential oil area along the west flank is about 14,250 acres. The proven crude acreage to date totals 8,665 acres—7,265 acres in the South End of the field and 1,400 acres in the North End of the field. Between these two areas there is a



© H. Pollard

Royalite production battery in South Turner Valley.

section which has yet to be definitely proven. The recent completions of three wells in the central part of the field have added 2,150 acres to the proven areas.

The stratigraphy of the formations drilled is fairly uniform throughout the field both in the gas cap and the crude oil area. Excellent markers are encountered in most of the sections and can be readily determined by examination of the well cuttings without the use of micropalaeontology. Because of this, very little coring, except in producing zones of the limestone, has been done in the field.

The wells in the gas cap started in the Alberta shales (Colorado of Upper Cretaceous), while most of the crude wells start in the Belly River series (Montana of Upper Cretaceous) lying immediately above the Alberta shales. The Belly River series contains alternating bands of fresh water shales and sandstones. The character of the sandstones varies throughout the field as in certain areas they are hard and cause crooked holes, while in other parts, no difficulty is experienced in drilling a straight hole with good bit footage. It is probable that the dip of the formation may account for some of this, since dips up to 60 deg. are not uncommon in the upper formations.

In the Alberta shales, the top is characterized by a hard sandy series approximately 300 ft. thick which has to be drilled with care due to tendency of the hole to deviate from vertical. The remainder of this formation consists mainly of marine shales and sandy shales, some sections of which may give caving trouble. The thickness of this formation is usually about 2,700 ft. The Blairmore formation which is a fresh water formation of Lower Cretaceous Age is next encountered. The upper 1,000 ft. of this formation is made up of alternating green and grey shales which drill fairly easily, while the lower 200 ft. is a marine facies with hard limestones and limy sandstones. Although these members usually do not cause any crooked hole, the drilling speed is decreased considerably and bit footages may be reduced to one foot per bit. Below this, the Kootenay (Lower Cretaceous) coals, coaly shales and sandstones occur with a thickness up to 100 ft. followed by the Fernie (Jurassic) in which there are brownish sands at the top, grading into black marine fissile shales. These fissile shales may cave rather badly in some areas and give trouble while drilling. The thickness of this formation is approximately 200 ft.

The producing limestone is next encountered, the top of which is characterized by a thin chert conglomerate. There are two principal producing zones, the Upper Porous Zone and the Lower Porous Zone. The Upper Zone is almost a pure dolomite and is a very continuous horizon ranging in thickness from 75 to 100 ft. Between the zones, there is approximately 75 ft. of hard dense limestone with chert bands. The Lower Zone is also dolomitic and its thickness varies from 20 to 120 ft. In the centre part of the field, this zone shows practically no porosity. Drilling is usually stopped when a dark grey limestone below the lower zone is penetrated, as no appreciable porosity occurs below this marker.

EQUIPMENT

In the early development of the field, all drilling was done with cable tools. The first rotary equipment to be used was installed in 1925. During 1929 and 1930, when there was a drilling boom along the gas cap, the use of rotary equipment increased rapidly and approximately half the wells were drilled with rotary tools. Since the crude oil development started in 1936, rotary equipment has almost entirely displaced cable tools.

Rotary drilling equipment is well standardized in the field. Steel derricks, 136 ft. high, usually without sub-structure are now used almost exclusively. Modern heavy-duty unitized draw works with 9 or 10 in. drumshafts and with either a 12 by 12 in. or 14 by 14 in. horizontal engine are installed at all wells.

© H. Pollard

Looking north from Little New York in South Turner Valley

Mud circulation is handled usually with one 16 by 8 by 20 in. pump and one 14½ by 7½ by 18 in. pump. Some contractors utilize separate units with 7¾ by 7 in. or 9 by 8 in. engine for driving the 20½ or 27½ in. rotary tables. Crown blocks and hook are of 300-ton type, while travelling blocks are of the 80 or 88 in. size. Vibrating screen shale shakers are considered as essential equipment by most operators.

Steam is used on all rigs as there is a good supply of water and gas at most locations and it is essential for winter drilling. A few power driven slush pumps are used in order to reduce boiler equipment. At most locations, three 125 h.p. boilers carrying 250 or 300 lbs. of steam are standard equipment while zeolite water softeners are in operation at several locations.

Certain preparations are made for winter drilling operations. The derrick is covered in as much as possible and steam heaters are used extensively in order to prevent freezing of various parts of the equipment. It is essential to blow out all mud lines and water lines with steam when not in use to prevent freezing. It is necessary to hook up rat hole so that circulation can be maintained through the kelly when it is not in use. Thus, considerable added expense is entailed in rigging up for cold weather drilling.

Rock bits are used exclusively, as earlier attempts to run drag bits proved uneconomical in the varied character of the formations. Bit footages vary greatly depending on the formation drilled and may run as high as 200 ft. in the upper formations, while one or two-foot runs are not uncommon in the limestone.

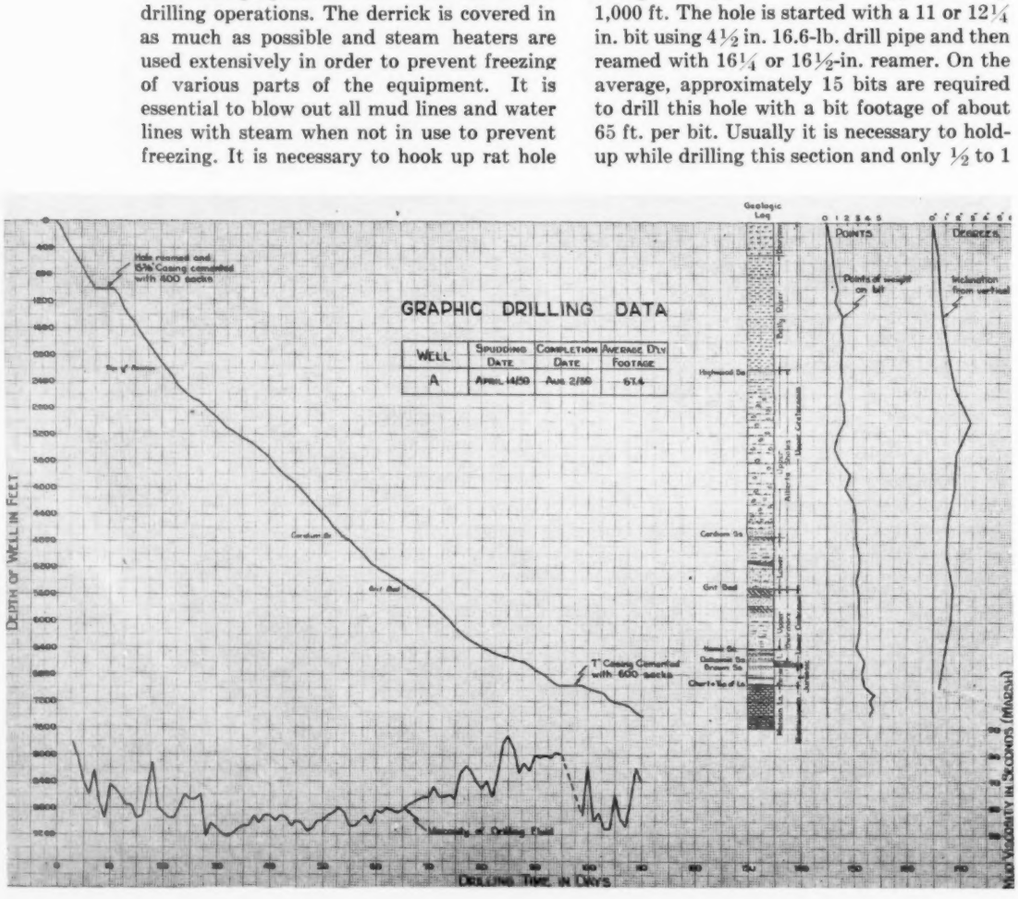
DRILLING PRACTICE

The present casing program for rotary wells adopted by most operators is to cement a string of 13⅜ in. casing at approximately 1,000 ft. The hole is started with a 11 or 12¼ in. bit using 4½ in. 16.6-lb. drill pipe and then reamed with 16¼ or 16½-in. reamer. On the average, approximately 15 bits are required to drill this hole with a bit footage of about 65 ft. per bit. Usually it is necessary to hold-up while drilling this section and only ½ to 1 point of weight is carried on the bit. While the endeavor is to keep the inclination of the hole to one degree or less at times it will run as high as two degrees despite weights on bit of ¼ to ½ a point. The 13⅜ in. casing is cemented with 400 sacks of quick-set cement after which drilling is resumed in 24 hours.

Most operators then drill a nine-inch hole with 4½ in. drill pipe to the top of the producing limestone which may be encountered at depths from 7,000 to 8,500 ft. The hole is drilled 10 to 15 ft. in the limestone and seven-inch casing is set with 600 sacks of cement. The formations cut by these bits are varied and bit footages and drilling speeds are dependent on the section drilled. As previously mentioned, some parts of the section are particularly conducive to crooked hole and consequently it may be necessary to carry as low as ¼ point of weight on the bit to keep within maximum inclination of four degrees allowed by the Government Conservation Board. These deviations are more likely to occur above 5,000 ft. and average weight on bit to this depth is usually about 1½ points with a maximum of three points. From 5,000 ft. to the top of the limestone, most holes do not migrate to any appreciable extent and three and four points of weight can be carried without any difficulty. For 24 wells completed in 1939, the average number of nine-inch bits used was 178 per well while the average bit footage was 43.5 ft. per bit and the average speed was 2¾ ft. per hour.

Drilling is resumed in the limestone approximately three days after the seven-inch casing is cemented. A 6⅛ in. hole is then drilled with 3½ in. 13-lb. drill pipe through the two porous zones to the black lime which is encountered at 425 to 475 ft. from the top of the limestone. Some coring is done in the porous zones although difficulty has been experienced in obtaining good recoveries. For 22 wells drilled in 1939, the average number is 6⅛ in. bits used was 41 per well while the average bit footage was 12.5 ft. per bit and the average drilling speed was 2.0 ft. per hour.

The present cost of bits in Turner Valley,



less exchange on money, is $124.00 per bit for 11-inch, $96.00 per bit for nine-inch and $72.00 per bit for 6⅛ in.

Average Well Bit Costs

Size of Bit	No. of Bits	Total Cost
11-inch	13	$ 1,860.00
9-inch	178	17,088.00
6⅛-inch	41	2,952.00
Total		$21,900.00

It can be seen that the field is not conducive to fast drilling times, mainly due to its complicated structure and difficulties with straight-hole drilling. Rapid strides have been made, however, since 1937, and despite deeper drilling, completion times have been decreased markedly. The best daily average footage up to 1936 was 42.8 ft. per day to the completion depth of 6,125 ft., while the present record time for completion held by Royalite Oil Company is 110 days to a depth of 7,415 ft. or an average of 67.4 ft. per day. In 1939, the average completion time for 21 wells was 171 days to an average depth of 7,887 ft. or 46 feet per day.

Although improvement in drilling equipment and drilling bits has undoubtedly increased the drilling speed, straight hole drilling and better control drilling mud have been important factors in the reduced drilling times. Prior to 1937, little or no attention was paid to these phases of drilling. Straight hole drilling has been accomplished by accurate control of weight on the bit, use of long drill collars and faster rotation of the rotary table. For drilling the nine-inch hole, 6⅝ or seven-inch drill collars are used, the length varying from 90 to 150 ft. In the limestone, only one 4⅝ in. drill collar 20 ft. long is used. The speed of the rotary table is dependent on the contractor but one major operator rotates at 300 r.p.m. at the top of the hole with a gradual decrease to 150 r.p.m. at the top of the lime. In the limestone the speed varies from 50 to 100 r.p.m.

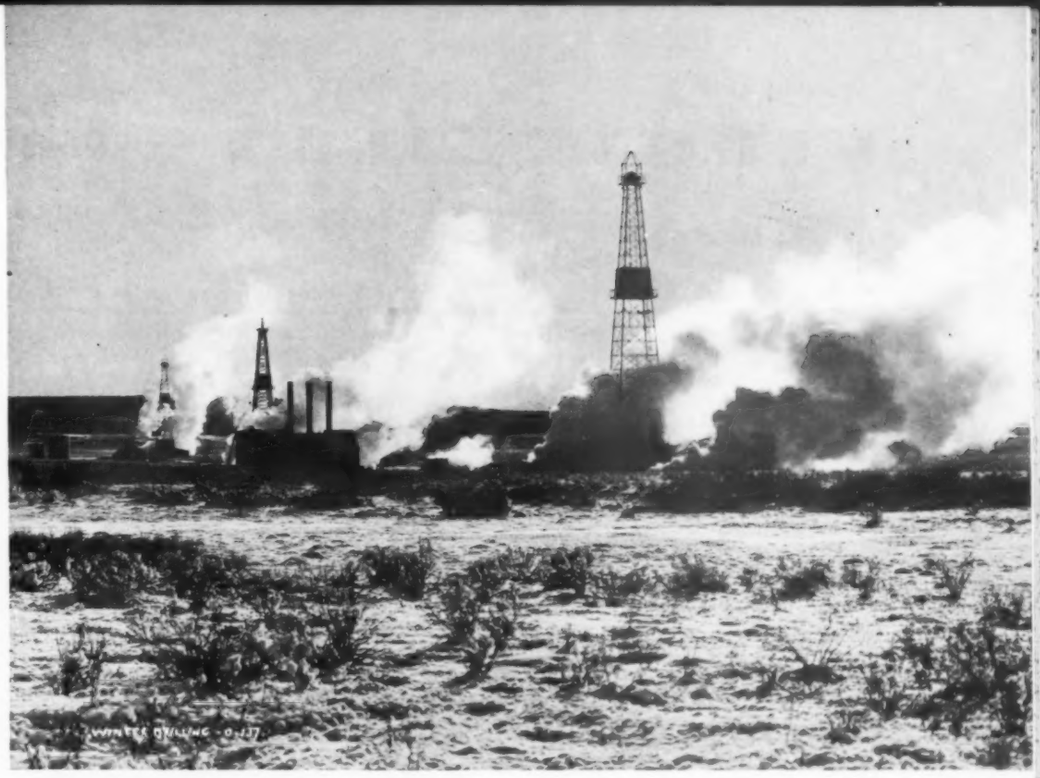
Since most of the formations penetrated do not make a good drilling mud, the addition of local clays or commercial bentonites is necessary. Some contractors favor the use of bentonite from top to bottom, while others utilize various combinations of the two. Experience to date has shown that the higher-viscosity muds have given the best results. An average of the viscosities maintained at several wells by one major operator is given as follows:

Average Mud Viscosity Maintained by One Operator

Depth feet	Viscosity[1] seconds	Formation
0—2,000	65	Belly River
2,000—4,000	70	Belly River and Benton
4,000—6,000	75	Benton and Upper Blairmore
6,000—6,700	85	Upper Blairmore
6,700—7,000	140[2]	Upper Blairmore
7,000—7,400	85	Lower Blairmore and Lime.
7,400—7,850	65	Limestone

[1]Marsh Funnel—A. P. I. Method.
[2]Increase due to loss of circulation.

The mud used in these averages consisted of a mixture of bentonite and local clay above the limestone while pure bentonite was used for drilling the limestone. It will be noted that there is a loss of circulation between 6,700 and 7,000 ft. in the above wells. This loss is encountered in most walls and occurs in a coarse sand in the Middle Blairmore. No great difficulty is usually experienced in regaining circulation by thickening the mud although at times it is necessary to add saw-dust to prevent large losses of mud.



Winter drilling in Turner Valley, as pictured above requires added precautions to prevent freezing of various parts of the equipment.

© H. Pollard

Weighting materials have been tried with varied success but they are not essential because no high pressure gas zones are encountered above the limestone. In the limestone the hydrostatic head of the mud column is greater than the reservoir pressures while no appreciable gas cutting of the mud occurs.

For drilling in the limestone, either a straight bentonite mud or a heavy crude oil is used. It has been found that bentonite mud at viscosities of 50 to 60 seconds with Marsh Funnel (A. P. I. Method) are usually sufficient to prevent appreciable loss of water in the porous producing zones. This mud will carry fine limestone cuttings up to 50 percent of total solids in suspension, and the mud cake formed is easily broken down with acid. When oil is circulated, still bottoms of about 27 deg. A. P. I. gravity with a high flash point are usually used. The time of drilling may be slightly longer with the use of oil and although some oil may penetrate the porous zones, the results to date have been satisfactory.

STATISTICS

In 1939, 35 wells were completed in Turner Valley with initial productions ranging from a few barrels per day to 1,000 bbl. per day. At present, the total number of crude producers is 108, and there are 103 gas cap wells. All crude wells are acidized at least once, while most wells are given at least two or three treatments. Good increases are obtained from acidization in practically all wells, and the largest producer to date had a flush production of 5,000 bbl. per day. The total amount of acid varies with individual wells and ranges from 4,500 gal. to 35,000 gal. per well.

A summary of wells completed, total footage drilled and total crude oil production for years since discovery of crude oil is given in the accompanying table.

Year	Total Footage Feet	Crude Oil Wells Completed	Total Crude Oil Production* Barrels
1936	52,470	3	319,845
1937	245,531	27	1,916,110
1938	303,112	39	6,029,010
1939	281,274	35	7,180,161

*History of Alberta Oil. F. K. Beach & J. L. Irwin, Dept. of Lands and Mines.

The cost of drilling and equipping a well for production in Turner Valley varies from $175,000 to $200,000. The present scale of contractors' prices for a turnkey job is $150,000 for a well 7,000 feet and $22 to $25 a foot below this depth.

Under the present regulations of the Government Conservation Board, all wells are limited to 40-acre spacing on the assumption that this should adequately drain the various areas. The gravity of the oil ranges from 40 deg. to 50 deg. A.P.I. depending on the position on structure.

Due to limited available markets, the field is prorated under the supervision of the Government Conservation Board. In 1939, the daily allowable varied from 10,000 bbl. per day in the winter to 27,000 bbl. per day in the middle of summer, with a weighted average of 19,180 bbl. per day. The present potential of the field just allows economic and efficient production at the higher rates of flow. It appears that it will be necessary to complete 25 to 30 wells a year for the next two or three years in order to maintain this rate of efficient production. If the market requirements are increased, the number of completions will have to be raised accordingly.

GEOCHEMICAL Exploration Comes of Age

By W. R. Ransone
Geophysical Service, Inc.

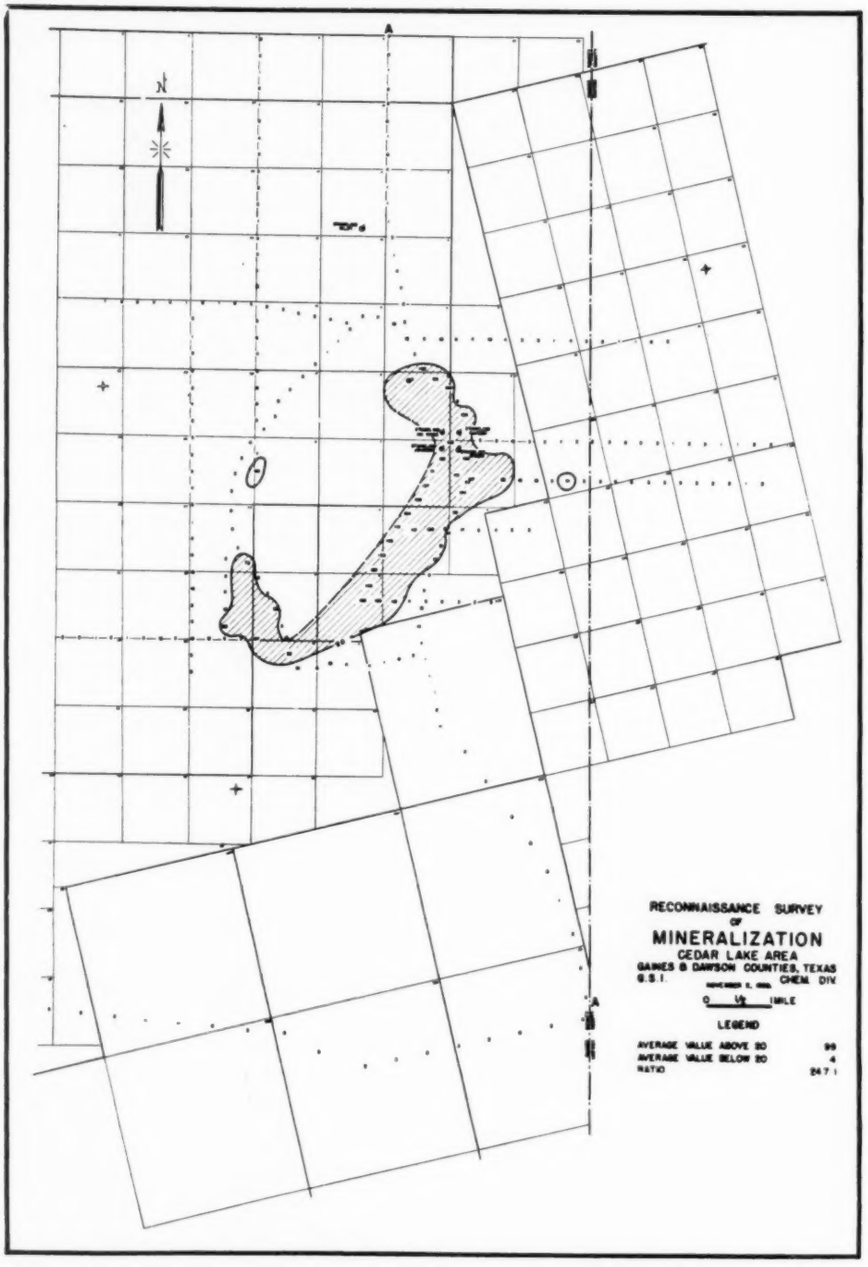


Figure 11

THE oil prospecting method called geochemical exploration (or soil analysis) has now entered into the last stage of growth; that is, widespread commercial use. At the inception of this method, many problems were encountered which demanded solution before the germ of the new idea could develop into the mature method. As the more important of these problems have been solved, the method has passed through the childhood period of research, and the adolescence of experiment, into the fully developed personality and character of commercial usefulness.

The first of the research problems was to discover if any distinct leakage pattern occurred in the surface materials, and whether or not this pattern could be used to locate the oil or gas accumulation with respect to it. The earliest petroleum geologists recommended successful drilling sites near oil and gas seeps leaking from underground deposits, but they did not report any pattern; consequently their location of wells was haphazard. Along with the search for a pattern came the problem of determining what substances were pattern forming and present in measurable quantities. With these two early problems outgrown, there arose the problem of determining when the constituent or substance measured was of a concentration sufficiently high to rise above the variations in normal or background concentrations; in other words, what concentrations were significant. The solution of these problems has been accomplished and makes an interesting story far too long and detailed to be fully treated in anything less than a full-sized volume. An attempt is made here to cover only the most important points and still to present a complete picture.

In attempting a solution of the first problem, the early observers generally conceded that the hydrocarbons themselves, leaking from the oil or gas accumulations, should be found occluded to, or occupying the interstitial spaces of the surface and near surface soil particles. The Russian observers assumed that the hydrocarbons would be found on the surface concentrated over the oil deposit. They selected the gaseous portion of the hydrocarbons since these were assumed to be easier to extract from the soil and proceeded to try soil surveys from analysis of soil air over many oil and gas fields in Russia. Their carefully prepared reports include many maps which do show patterns over the accumulations, and it is interesting to note that many of these maps show a high concentration over the margin of the field. V. A. Sokolov in the NEFTYANOYE KHOZYAYSTVO, v. 27, 1935, wrote "In the center of the region of maximum hydrocarbon content a relative minimum occurs, in which the hydrocarbon content has the same value as in the zone which borders the region of maximum content. Our attention is attracted by the fact that this relative minimum within the region of the maximum hydrocarbon content coincides with the western dome of the Ishimbayo field". This was about as close as the Russians ever came toward recognizing the halo type pattern which Rosaire pointed out later was one of the principal patterns, and which he named.

Rosaire, McDermott and other American observers followed up this lead and began to examine their maps with the idea of finding halo patterns. At the same time, they also began measuring other phases of the hydrocarbons as well as certain minerals which appeared to form patterns correlative with the hydrocarbons. As time passed, surveys were conducted over many producing areas and it became obvious that the halo type pattern was one of the principal patterns. Other patterns were also encountered, in-

cluding the high-over-the-accumulation pattern which had been looked for so assiduously by the Russians. Also the pattern related to faulted and stratigraphic traps became known and recognizable. Figure III illustrates the three most important patterns.

This solution of the first problem is well illustrated by referring to Figure I, a hydrocarbon map of the Cedar Lake area, Gaines County, Texas. This map exhibits the halo pattern where the high hydrocarbon content occurs directly over the margin of the oil body. At the time this reconnaissance survey was run, the discovery well of the Cedar Lake field, Stanolind Rayner No. 1, had just been reported. The 270 analyses which were made on this prospect are not sufficient for more than a reconnaissance survey. The halo is not quite complete, and the addition of more sample points would doubtless tend to make it more complete. However, it is important to point out that lack of total annulation is the rule and not the exception with this type of pattern. Figure IV shows a cross-section over the field and the size of the anomaly is well illustrated. The halo is not apparent due to the location of the cross-section.

This recognition that oil fields do leak and do form observable patterns on the surface is a matter of fact, and not a theory. The importance of this fundamental discovery cannot be brought out too strongly. It has been checked by the analysis of hundreds of thousands of samples taken over scores of oil fields.

In the course of the search for definable patterns, it was only natural to test soil samples for all possible elements in an effort to find those which were present in greatest abundance, and to select from these those which could be subjected to routine analysis. This second fundamental problem, the selection of a constituent for analysis, has also been solved and routine analysis techniques put into production. Oddly enough, it was discovered that almost everything that was present to be so concentrated, was found to be concentrated along with the hydrocarbons. This includes the three phases of the hydrocarbons, namely: gaseous, liquid, and solid. Also present were many inorganic substances, certain of which were referred to as minerals, or mineralization.

Again referring to Figure I, the analysis values are based on measurement of heavy hydrocarbons, and it is important to note that they reach amounts as high as two percentum by weight. Figure II illustrates a mineralization pattern that is a close match to the hydrocarbon pattern. This mineralization phenomenon is frequently found forming patterns correlative with the hydrocarbon patterns and is proof of the statement

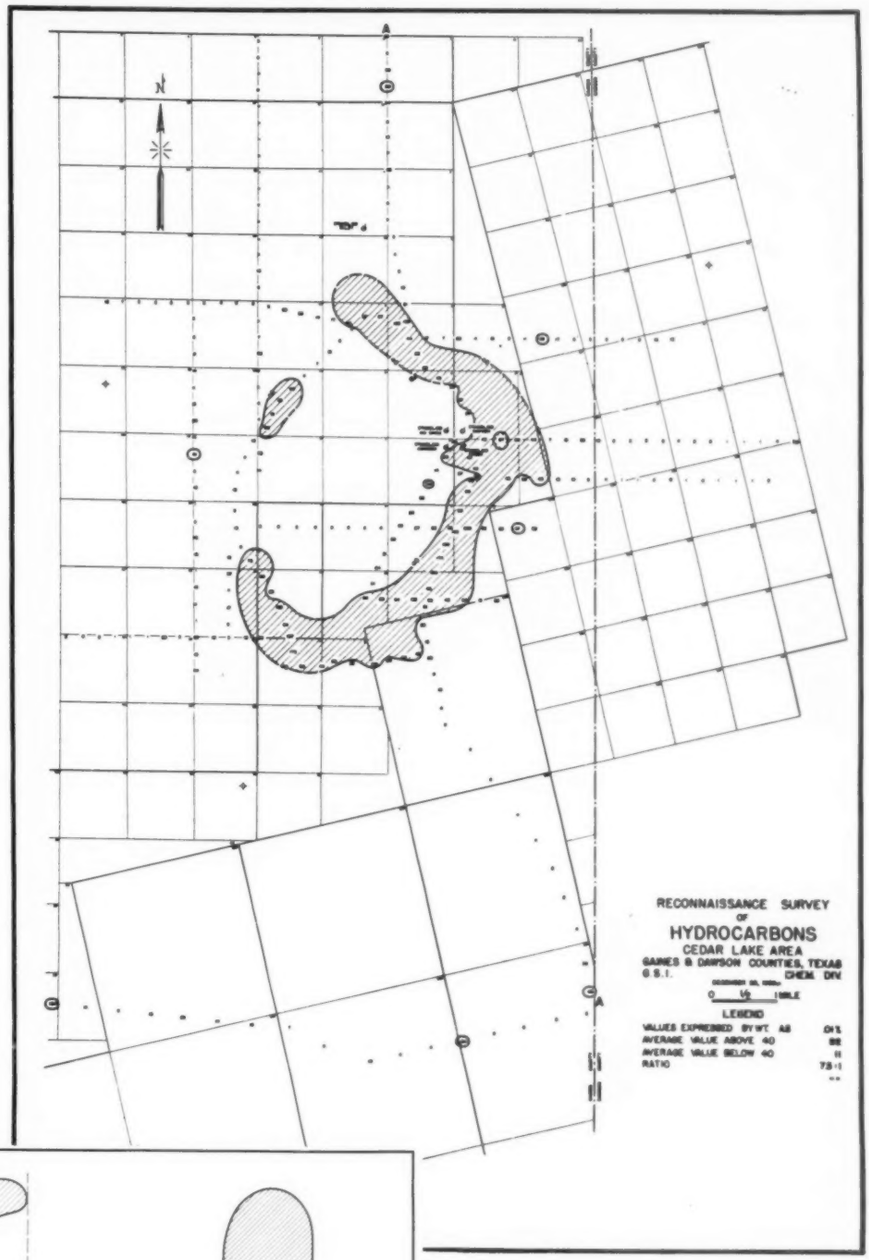
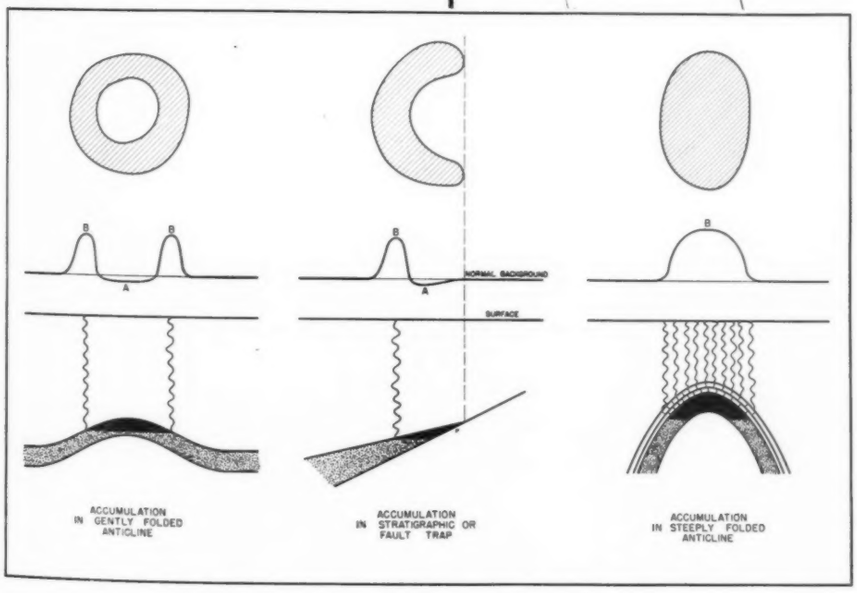


Figure I

Figure III



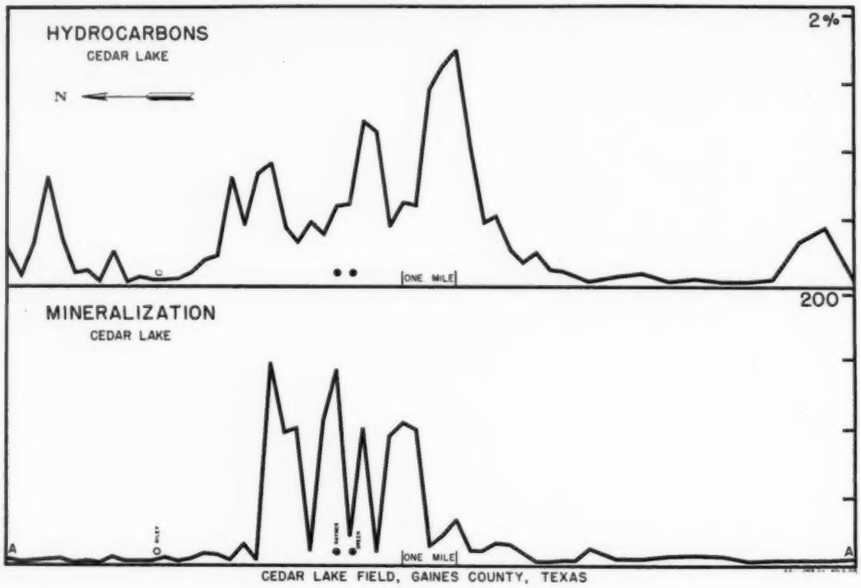


Figure IV

made above that many different substances are found to be concentrated in conjunction with the hydrocarbons. Here again we are dealing with fact, and this observed evidence fits well with the theory of formation of the surface patterns. The theory is that the gaseous portions of an oil accumulation escape and move to the surface of the ground through microscopic fissures and fractures. As they move toward the surface polymerization takes place and upon analysis of surface soil samples all three phases of the hydrocarbons are found to be present. Also, these same gases, moving toward the surface, transport to the surface various soluble minerals native to the formations through which the gases pass.

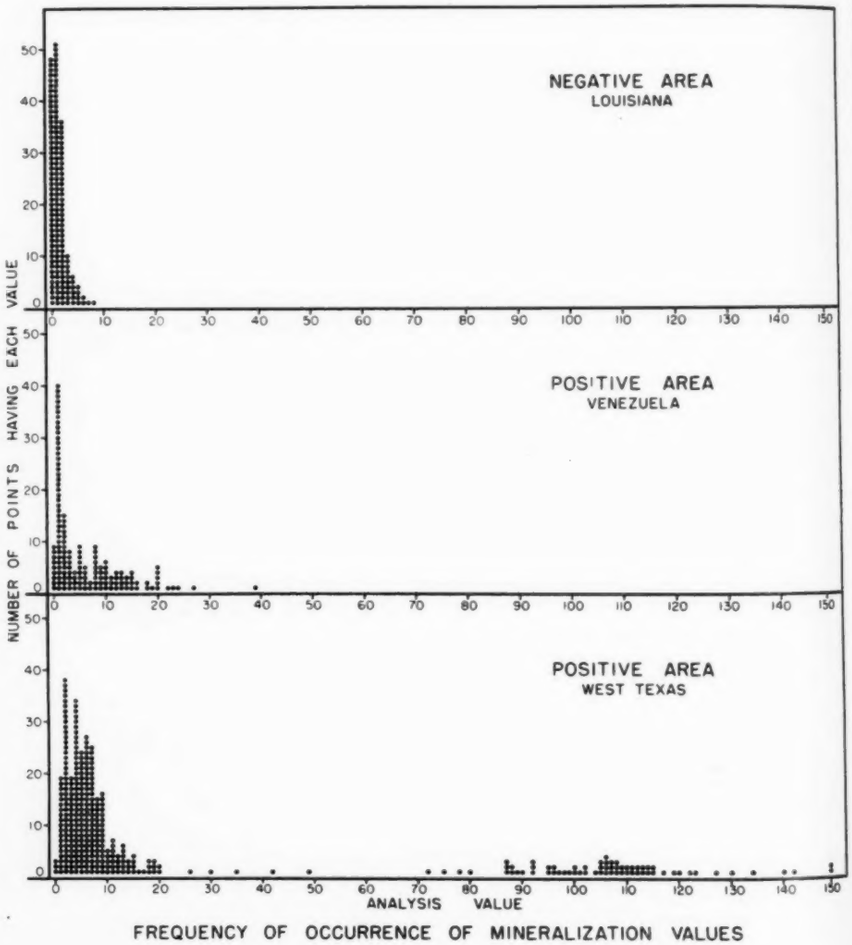
The use of the solid phase of the hydrocarbons has been generally discontinued since these solids, sometimes called waxes, occur mostly in the top fractions of an inch of the soil and as a result of this position are subject to every possible disturbance, including erosion, plowing, contamination, etc. The hydrocarbon gases are present in quantity at depths of five or ten feet, as are the heavier hydrocarbons, and as this depth is below all ordinary surface effects, analysis for these constituents at such depths is a satisfactory technique. However, as the heavier hydrocarbons occur in greater quantities than the gaseous, they are better suited to accurate routine analysis, and therefore give more reliable results.

We have now come to the third problem, which is the necessity of deciding which analysis values are high enough to be significant and therefore pattern forming. Before this problem can be properly attacked, experience has to be gained in various areas over both productive and non-productive acreage. This experience has been obtained in a great many states of the United States, including Texas, California, Oklahoma, New Mexico, Louisiana, Arkansas, Illinois, Ohio and Pennsylvania, and in several foreign coun-

Mapping results of laboratory analysis of field samples.

Robert Yarnall Richie

Figure V



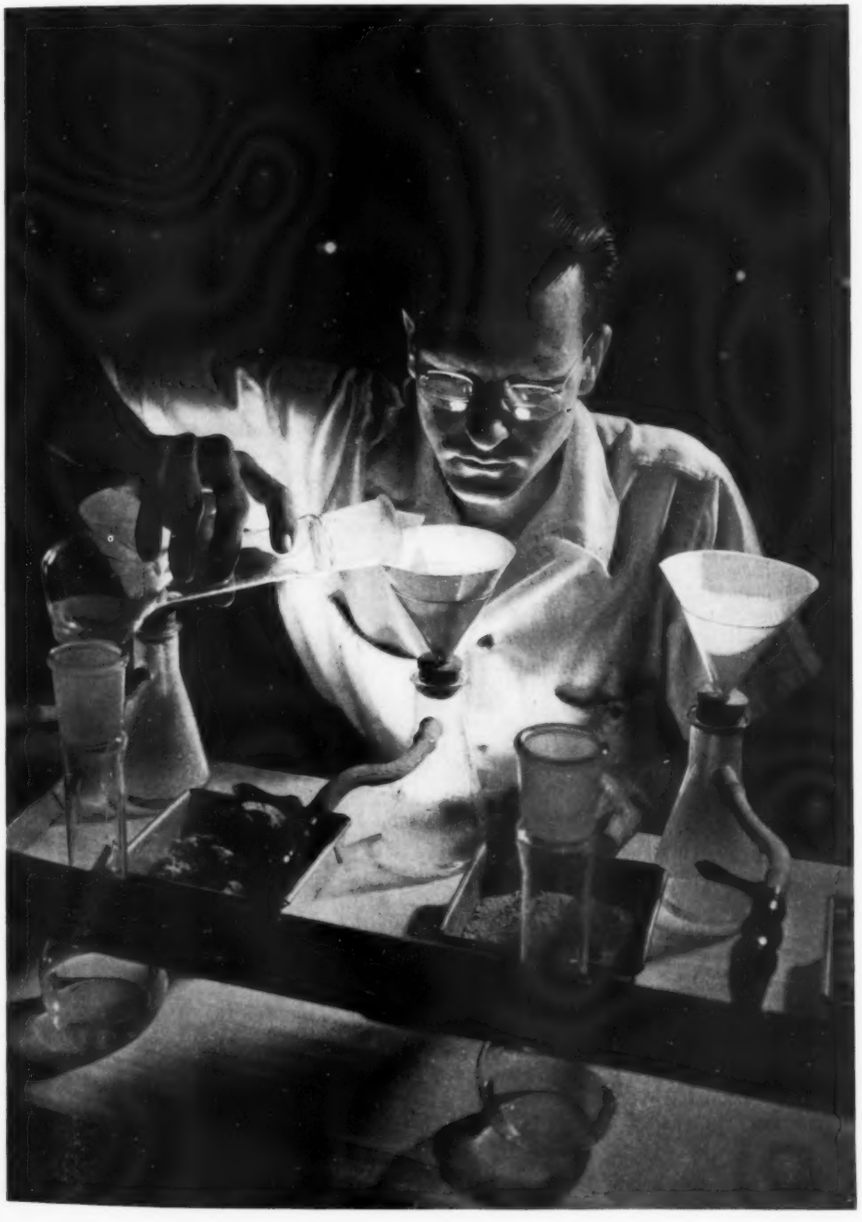
FREQUENCY OF OCCURRENCE OF MINERALIZATION VALUES

tries, including Venezuela, Argentina and Colombia.

However, experience alone is not the only determining factor in this problem, for it is really one of applying certain well-known principles of statistics commonly used in engineering and the sciences. The statistical theory involved is that variations in normal or background analysis values are due to chance, and, therefore, should distribute themselves under a probability curve. Any values which do not fall under this probability curve are significant in that they are due to a secondary source of the constituent measured, which adds to the background of that constituent.

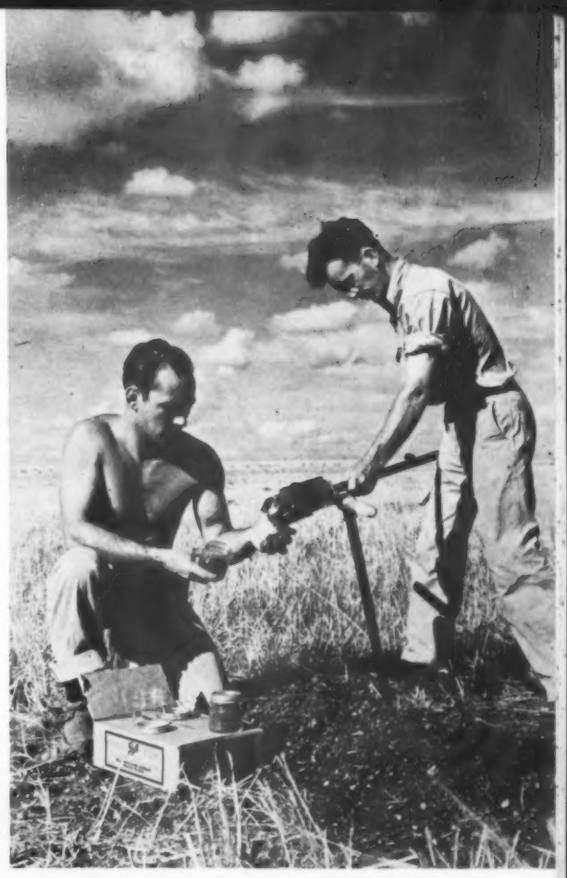
The first step in examining data for the possibility of significant values is the plotting of the frequency distribution of the analysis values. This is done by plotting the analysis values along the abscissa, and the number of points having a particular analysis value on the ordinate.

In Figure V the top frequency curve is from an area in Louisiana which is known to be non-productive because dry holes have been drilled there. Note that the frequency curve simulates a normal probability curve and it can be definitely said that values less than nine are not significant. The middle graph in Figure V is a positive area for wells tested on this prospect have produced oil. The normal probability curve is slightly masked because the significant points begin to appear at value ten and add to the right half, making the entire curve skew to the right. This type of curve would be recognized as positive, but it is not as clear cut as are the cases illustrated in the graphs above and below. Indeed, it is this type of marginal prospect which has caused so much difficulty with the geochemical method of prospecting. The very fact that it can now be identified is of great importance. The third and lower graph in Figure V is illustrative of a definitely positive area. Here we have the normal probability curve well developed to the left and the significant values forming a second curve far out to the right and strikingly separated from normal values.



Laboratory analysis of uncontaminated field samples, studied for evidence of hydrocarbon concentration on mineralization.

Robert Yarnall Richie



Gathering earth samples in the field for laboratory analysis

Any values above twenty are significant in this area and a final step in this statistical scheme is to contour the map, using a contour value of 20. In this instance virtually all of the values thought to be significant from examination of this frequency curve are found to be adjacent on the map, and also pattern forming.

As mentioned above, this is the first approach using statistical methods, and more rigorous and subtle methods may be applied after this start; but it is true that this simple scheme of using frequency curves allows very important decisions to be made. For instance, in the above curves we have been able to separate definitely positive areas, definitely negative areas, and lastly the always troublesome marginal areas. Summarizing the above discussion, we find that all the fundamental problems of geochemical prospecting have been solved; analytical laboratory procedure is routine; the constituents measured occur in large quantities and are pattern forming; indeed, the principal patterns are recognized; and lastly but most important, statistical methods are applicable for the determination of significant values.

The first valid direct method of oil finding has come of age and is taking its place with other exploration methods. Its use in conjunction with them should result in its greatest successes, and should increase the scope of their usefulness as well. The amount of geochemical exploration being carried on at present is large but it only the beginning of its use as a mature method.

DEEPER DRILLING Requires Improved Instrumentation

By G. L. Kothny

Accurate Information on Subsurface Conditions is the Sine Qua Non of the 20,000 ft. Well. An Expert on this Subject Describes Recent Improvements in Methods and Equipment.

During the past decade the producers and drilling contractors have become more straight hole conscious and have in their drilling operation made more extensive use of surveying instruments and services, in order to drill straight and less costly holes. They have through experience recognized the advantages and benefits resulting from the accurate knowledge of the course of the hole.

While during the last five years no developments of major importance in well surveying instruments have been made, a number of improvements to meet successfully the conditions encountered when drilling deep holes of 10,000 ft. or more, were made.

In these deep holes extremely high temperatures and high hydrostatic pressures are encountered. It is not unusual to find temperatures ranging from 225 deg. to 260 deg. in holes of more than 10,000 ft. depth and pressures ranging from 5,000 lbs. per sq. in. to 8,000 lbs. per sq. in. Although, when making a survey the instrument remains only a comparatively short time in these hot and high pressure zones of the well, meeting the high pressure and temperature conditions, presented a somewhat difficult problem. The failure to obtain a record means considerable expense in rig time on a deep hole.

Figures 1 and 2 show records of the temperature fluctuations inside the protective casing during the in- and out-run of a gyroscopic well survey. Temperatures are photographically recorded during a round trip; and on the curves are plotted against depth. Figure 1 shows records of a well located in the Gulf Coast, while Figure 2 shows similar records for a well located in California. The lowering, as well as raising speed, were about equal and averaged about 100 ft. per minute including a 25 second stop at each 100 ft. interval. It is interesting to note that in both cases the maximum temperature was recorded on the out-run and at a depth of about 2,000 ft. above the bottom of the hole.

As previously stated, the recorded temperatures are those inside the protective casing adjacent to the instrument, which explains the peculiar shape of the curve. Temperatures in the well are 20 to 25 deg. F. higher than those recorded at various depths on the in-run. The heat surrounding the protective casing has to penetrate through the walls of the protective casing and through the air surrounding the instrument before it reaches the recording thermometer.

The transfer of the heat from liquid to metal, through the metal and from the metal to the air, through the air and again from the air to the metal requires time; hence, there is a delay of the temperature increase in the inside of the casing as compared to the increase actually existing in the well.

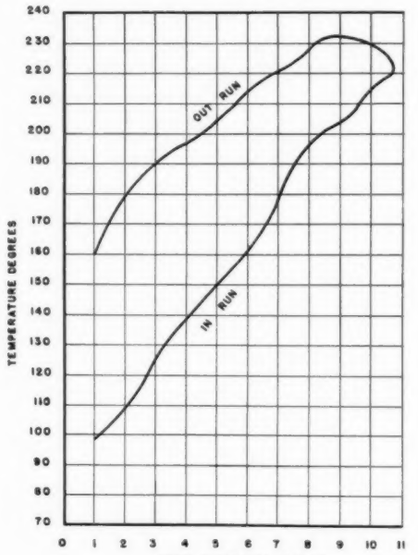


Figure 1

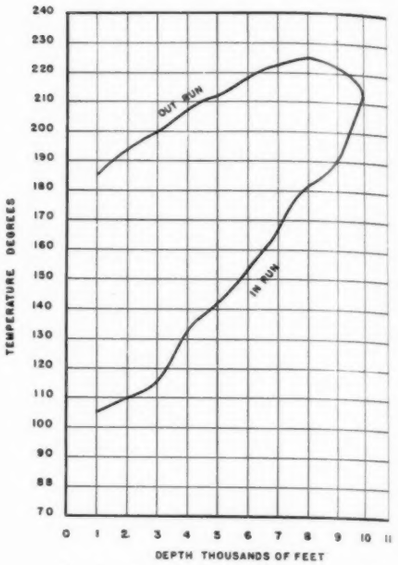
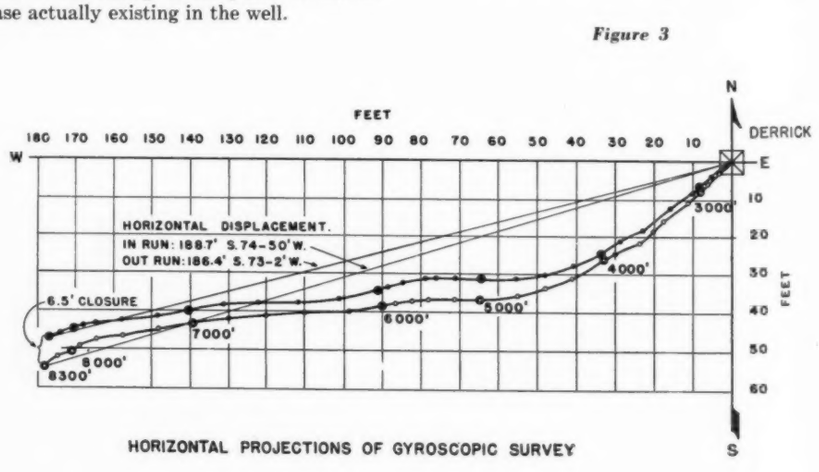


Figure 2

Since all the records are made photographically, the film has to be treated not only to resist these high temperatures, but also must be sensitive enough to produce sharp records with short exposures. So far it has been possible to obtain good records with temperatures as high as 245 deg. F.

To obtain the necessary safety factor against collapsing, special steel, having a very high yield point and at the same time of ductile structure, is employed in the manufacture of the tubing used as protective casing. A safety factor of two is considered ample. Special testing equipment consisting of a solid 12 in. by 12 in. square steel block, capa-

Figure 3



HORIZONTAL PROJECTIONS OF GYROSCOPIC SURVEY

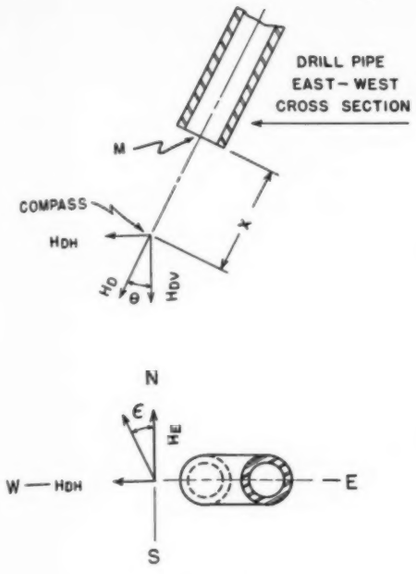


Figure 4

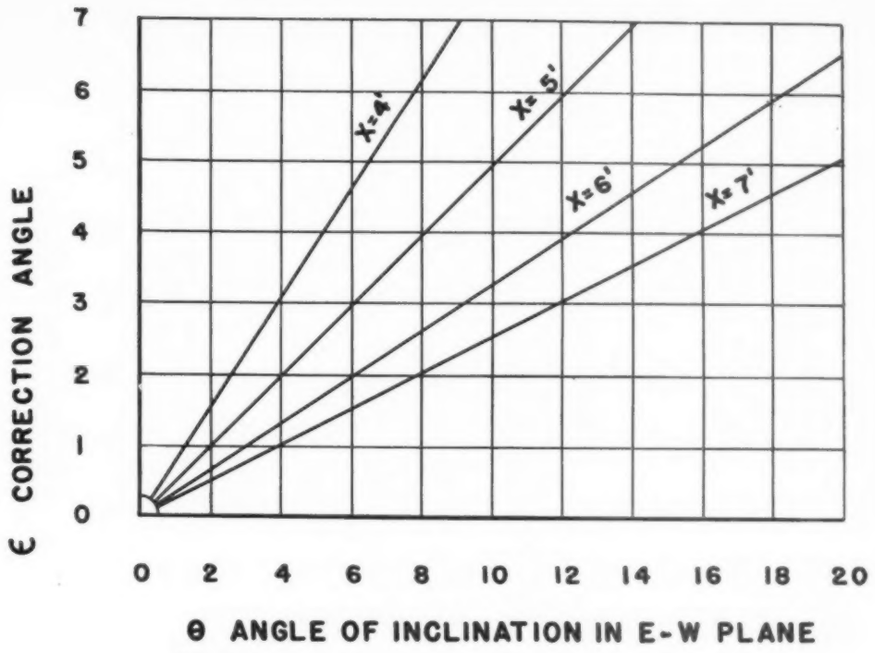


Figure 5

ble of holding pressure up to 20,000 lbs. per sq. in., of sufficient length and with an inside diameter large enough to permit the protective casing to be placed inside, is used for testing the casing and joints periodically against these high outside pressures.

To be assured of the accuracy of the survey, two surveys should be made in opposite directions; one on the in-run and the other on the out-run of the hole. Each of these surveys should be interpreted and plotted independently.

By placing the end of the plotted course of the out-run over the beginning of the plotted course of the in-run, a closure is established (see Figure 3) which proves the correctness and the accuracy of the survey. Closures of two to 10 ft. have been obtained on holes of over 10,000 ft. depth when being surveyed with a gyroscopic instrument.

Unless two surveys are made in opposite directions there is no assurance regarding the correctness of the survey. Since there is always an important reason for making a survey, it would seem advisable to obtain the assurance of correctness of the survey.

Surveys made with multishot instruments in which a magnetic compass is used for recording the direction, may be subject to erroneous recording, if magnetic influences of unknown magnitude and direction exist underground. Such surveys are also subject to the influence of the permanent magnetism of the drill pipe, tubing, or sinker bar and wire line, if off the vertical, which may affect the compass and cause an appreciable error in the recording of direction of inclination, unless correction factors are determined by actual tests and applied when interpreting the records of the survey. Figure 4 shows diagrammatically the effects of the permanent magnetism of the drill pipe, tubing or sinker bar upon the compass. The permanent magnetic force M of the inclined drill pipe exerts its magnetic force in reduced strength HD at the point where the recording compass is located. The horizontal component of HD, viz HDH if located in either an easterly or westerly direction will affect the position of the compass needle, which normally would be only under the influence of the earth's magnetic strength, but through the force of HDH will assume the position as indicated by the angle E known as angle of error.

To determine the angle of error, it is necessary to know the magnetic pole strength M at the end of the drill pipe and also the earth magnetic horizontal intensity HE; the latter can be found from maps published by the U. S. Geological Survey, while M will vary,

Figure 6

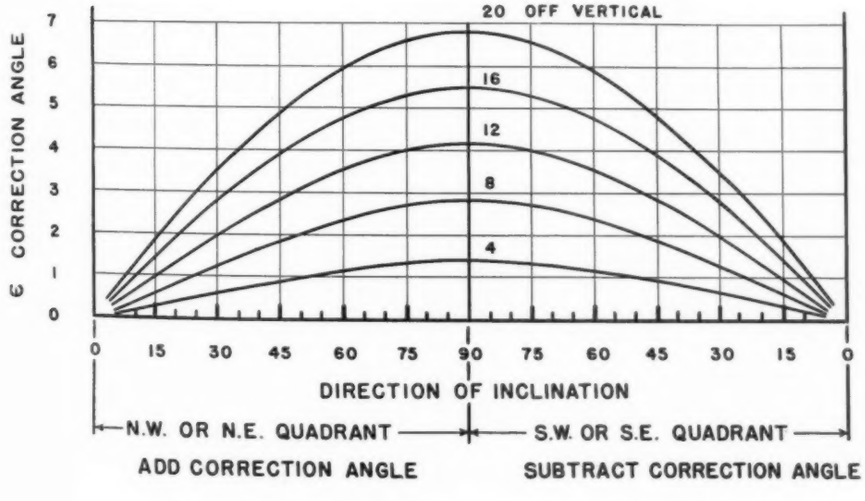
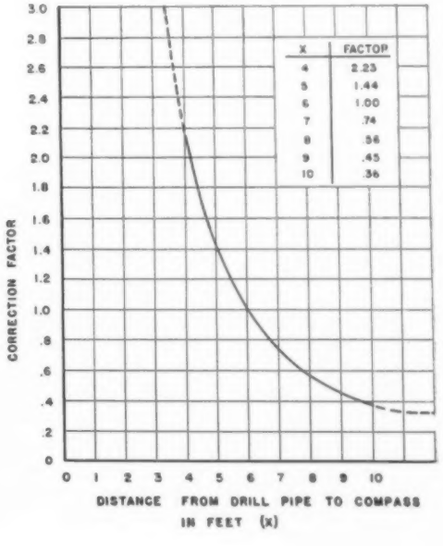
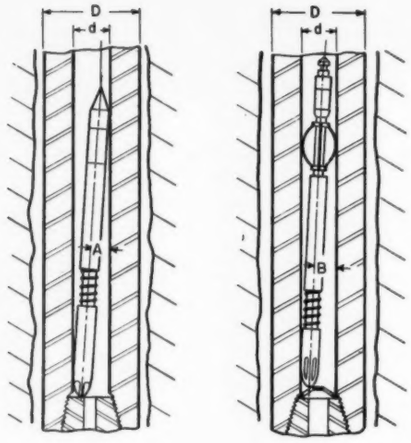


Figure 7





DRILL COLLAR		ERROR ANGLE	
D	d	A	B
10	4	1°-24′	0°-42′
8	3	0°-47′	0°-23′
7	2½	0°-28′	0°-14′
6	2	0°- 9′	0°- 5′

Figure 8

according to the size, length and assembly of the drill string and has to be established by tests.

Assuming M equals 3,000 E. M. U. and HE equals .257 oersteds we find

$$HD = \frac{M}{(305xX)^2} = \frac{3000}{(30.5\ X)^2} = \frac{3.225}{X^2}$$

Likewise we find

$$HDH = HD \times \sin\theta = \frac{3.225 \times \text{Sine } \theta}{X^2}$$

$$\text{Tangent } e = \frac{H.D.H.}{H.E.} = \frac{12.55 \text{ Sine } \theta}{X^2}$$

With the aid of this formula the curves in Figure 5 have been plotted, giving correction angles E for various angles of inclination in the magnetic East-West plane and for various lengths X in feet, and for a pole strength M of 3,000 E. M. U.

To make these curves useful for all angles of direction of inclination similar calculations as those above with a new variable, namely, the change of position HDH due to change of direction of inclination were made and the curves shown in Fig. 6 have been plotted for a distance X of six feet, and for a pole strength of M = 3000 E.M.U. and for an earth horizontal intensity HE of .257 oersteds.

It will be noted that the correction angle increases considerably with larger inclinations Also that in the NW or NE quadrant this angle is to be added, and in the SW or SE quadrant it is to be subtracted from the readings obtained.

If the reading is due west the correction angle must be subtracted from S 90 W and if due east the correction angle must be subtracted from S 90 E. Correction factors for variations in the distance X of six feet, to be applied to the curves shown in Fig. 6 are given in Fig. 7.

Due to the many variables, the correct interpretation of multishot magnetic surveys of inclined holes becomes somewhat complicated, but unless the angles of error are determined and correctly applied, inaccurate surveys maps will result.

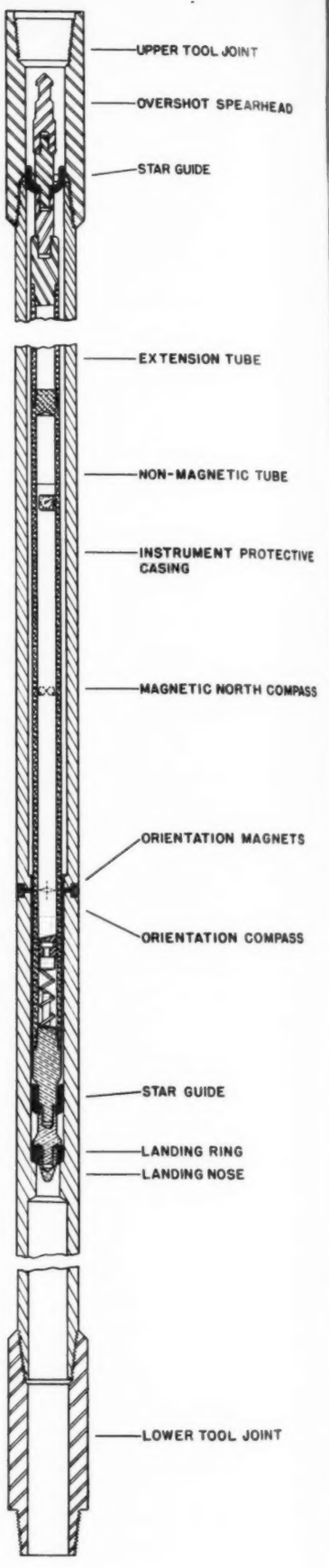
When making inclination records inside drill pipe instrument protective casings should be provided with guides on top and bottom of the casing to center the instrument properly and insure that its axis is parallel to that of the drill pipe.

If the axis of the instrument is not parallel to that of the drill pipe errors in recording due to the leaning of the instrument casing will result. Figure 8 illustrates this. The table below the figures gives the possible errors when using an instrument protective casing having an outside diameter of 1¾ in. and a length of 92 in. in drill pipes or drill collars having internal diameters from two to four inches.

Figure 9

Guides provided should be flexible to minimize frictional resistance, but still strong enough to center the instrument. A new star shaped type of guide made of reinforced rubber has recently come into use and given excellent results. Figure 9 shows this rubber star guide. It will be noted that in descending as well as ascending the fingers may bend in the opposite direction of movement, offering the least possible resistance through friction against the wall of the pipe

Figure 10



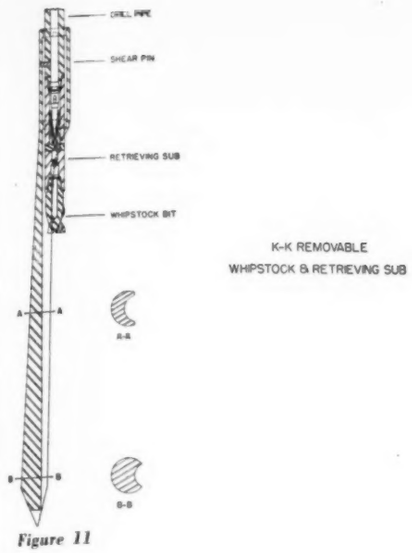


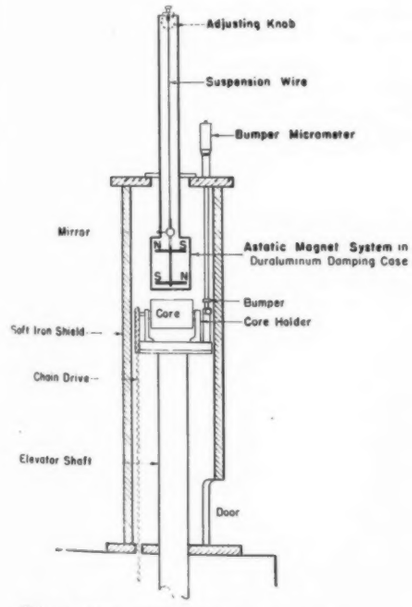
Figure 11

and mud fluid flow, with no swabbing effect.

The most important requirement of any well surveying instrument is that it produces accurate and not false or misleading records. To do this the instrument must be self-checking. The recording devices of the instrument must have come to complete rest at the depth at which a record is taken. If not, the record obtained should so indicate, to avoid being mislead by a false record. Liquid level or photographically recording instruments possess this most important characteristic.

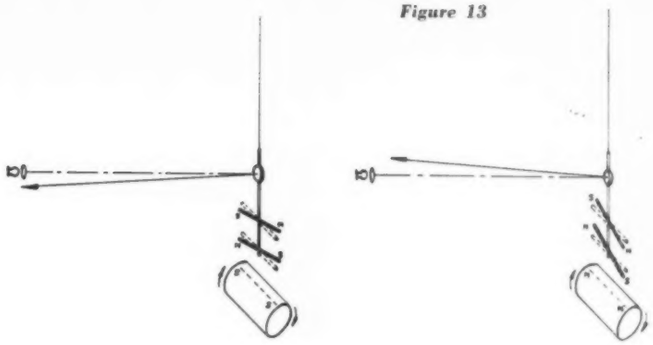
Instruments which can produce an easily readable record without the assurance that its recording device is at rest, should not be used. A false record taken in a deep hole may prove very costly.

Figure 12



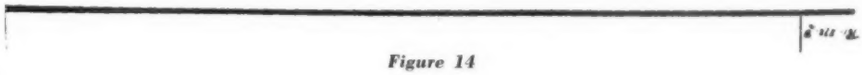
POLAR CORE ORIENTATION INSTRUMENT

Figure 13



REACTION OF MAGNETS TO ROTATING CORE

Figure 14



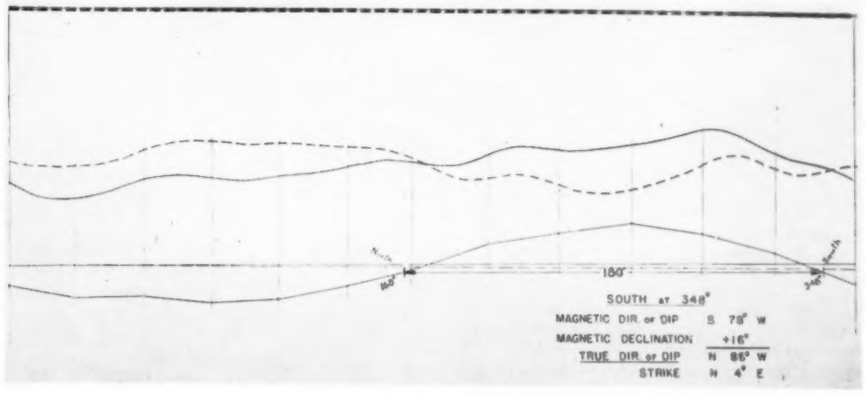
DIRECTIONAL DRILLING

The objects of directional drilling and its application have been dealt with in an article which appeared in the May 1936 issue of WORLD PETROLEUM. Directional or controlled drilling has increased considerably in volume and further increase may be expected, as deflecting tools and apparatus for orienting them correctly are now available to oil producing companies or drilling contractors, who prefer to do this work themselves.

During the past, deflecting tools were mostly oriented by recording at the surface the turns of the drill pipe when descending. A new and positive method for orienting deflecting tools correctly and obtaining a photographic record of the position of the tool prior to starting the controlled drilling has been developed and is now available under lease to producers and drilling contractors. It has been in successful use for over eighteen months by several production and drilling companies.

It is known as Magnetic Method of Orientation. A sub of non-magnetic metal is arranged in the drill string immediately above the tool to be oriented. The Sub is provided with two small magnets and a seating ring on which a Directional Magnetic Single Shot instrument can be landed. Figure 10 shows the instrument in place in the Sub. The instrument is equipped with an extra compass and when seated in the Sub, one compass is directly opposite the magnets, while the other is free to assume a true position in the North South Magnetic meridian. The extra compass is temporarily interchanged for the inclination unit in the standard single shot instrument. The relative azimuthal angle between the magnets and the direction of the deflecting tool face is measured prior to lowering the tools in the hole. The tools and drill string are lowered as is ordinarily done with the bit on

Figure 15



CORE ORIENTATION REPORT

DATE April 26, 1939 ORDER NO. POL— 513-LOS

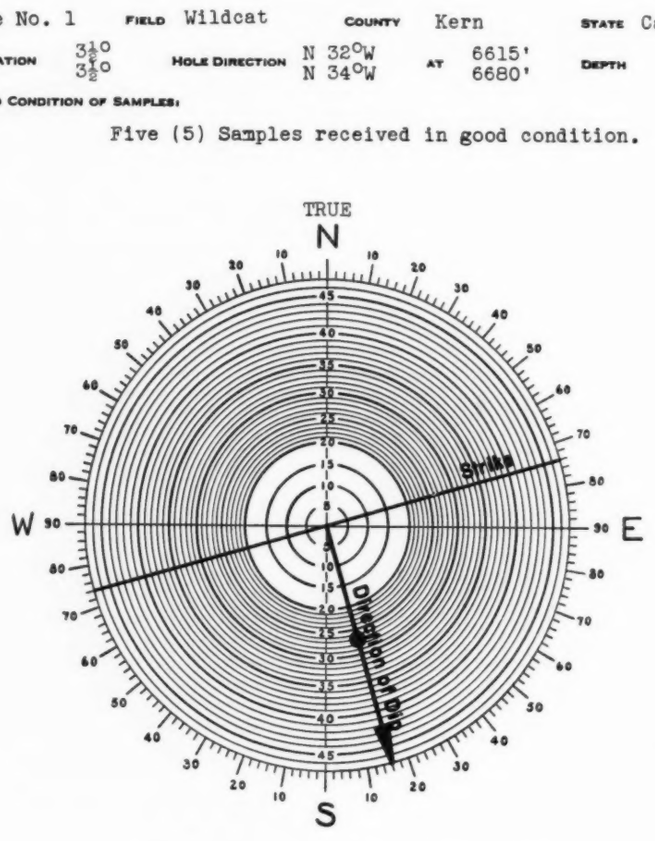
CUSTOMER Blue Oil Company TEST MADE BY E.R.W.

WELL Blue No. 1 FIELD Wildcat COUNTY Kern STATE California

HOLE INCLINATION $3\frac{1}{2}^{o}$ $3\frac{1}{2}^{o}$ HOLE DIRECTION N 32°W N 34°W AT 6615' 6680' DEPTH

NUMBER AND CONDITION OF SAMPLES:

Five (5) Samples received in good condition.



REMARKS:

Samples tested from: 6620', 6628', 6635', 6659', 6686'

Average Dip: 27°; Average Direction of Dip S 16°E; Average Strike N 74°E

Figure 17

the drill stem. After the tool has reached bottom the single shot instrument is used and a record is taken in the non-magnetic Sub. This record indicates the magnetic North and also the position of the deflecting tool in the hole since the compass located opposite the magnets is attracted by them. The tool is then rotated to bring it into the correct position, and other single shot record is made to check on the final position of the deflecting tool. The section of the compass needle with the black round circle indicates the direction of the tool.

The advantages of this method are:

1. It is speedy; deflecting tool and drill pipe are lowered as fast as the derrick equipment and crew handling it permit.
2. It is less expensive; the operation can be done by one man on the derrick floor.
3. It is positive and accurate; a photographic check record is obtained indicating that the deflecting tool has been placed in the desired position.
4. The employment of the non-magnetic sub makes it possible to obtain the direction of inclination inside of the drill pipe, avoiding a round trip of the drill pipe, thus saving rig time.

The non-magnetic sub is often arranged directly above the limber setup carrying the bit if used in connection with a whipstock or directly above the knuckle joint or spudding bit if the latter are employed. The material used in the construction of the non-magnetic sub has a yield point of about 60,000 lbs. and a tensile strength of about 100,000 lbs. It is non-corrosive and ductile and will outlast the drill pipe.

The magnetic method of orientation has reduced the cost of directional drilling, as not only the time for orienting the deflecting tool has been reduced, but with the positiveness of of the orientation with this method, failures which formerly occurred have been entirely avoided.

Another deflecting tool which has recently been made available to producers and drilling contractors under lease is the K-K Whipstock (see Figure 11). The whipstock has the inner face parallel with the axis of the drill pipe, and the taper on the outer surface, which makes it possible to provide guide walls throughout the effective length of the whipstock, thus eliminating the roll-off, which frequently occurs with the conventional type of whipstock.

The inner face of the whipstock being non-tapering, any wedging action of the bit between the inner face of the whipstock and the walls of the hole is avoided.

By making the inside of the whipstock in line with the vertical axis of the drill pipe and continuing this straight surface all the way to the bottom, the new hole will become practically a continuation of the old hole but in the new direction.

The whipstock collar has a large enough inside diameter to permit the bit to pass through it. The removal of the whipstock from the hole is accomplished by the use of a retrieving sub This sub is arranged immediately above the bit. It has two pins or latches which are held in a retracted position until released at will by the operator. The release is effected by dropping a Go-Devil, when ready to bring the whipstock out of the hole.

The pins or latches engage the collar of the whipstock. Depressions on the collars are provided to permit to turn the whipstock and rotate (screw) it out to prevent sticking.

The K-K Whipstock and retrieving sub have been used during the last ten months together with the magnetic orientation with outstanding results; the course of the controlled drilled hole with these tools being extremely smooth, assuring freedom from key seating.

CORE ORIENTATION

In the solution of geological problems and in exploratory work, the knowledge of the true direction of the dip of formations or fault planes is of great value.

Orientation of sample cores with good bedding planes will provide this important information. The methods used consist of marking azimuthally by mechanical or photographic means the top of the sample prior to the coring operation and at the same time determine the direction of the marker. When using these methods, it is not certain that a good sample will be obtained, nor that

Figure 16

the sample will contain good bedding planes.

Sometimes three to four round trips are necessary before a core sample suitable for determining the direction of dip is brought out of the hole, which makes the orientation by this method very costly.

To avoid taking oriented cores with negligible results, the method of orienting core samples by their magnetic properties acquired from the earth magnetic field, was developed. When using this method, cores can be hand picked out of the core trays and chosen for desirable bedding planes and suitable sizes.

Many minerals acquire and retain a certain amount of magnetic polarity. Magnetite and Pyrrhotite are highly magnetic; Glauconite, Ilemnite, Chromite and Almandine are moderately magnetic, while sedimentary formations such as pure lime stones, anhydrites and dolomites show no polarity.

Polarity is the property of a mineral, which enables it to acquire and retain the polarity of the earth magnetic field. Susceptibility on the other hand is that property of a mineral, which enables it to acquire a magnetic field but not to retain it after the mineral is removed from the field.

Cores usually consist of a heterogeneous mass of various minerals, some of which retain the earth's polarity and others which indicate different grades of susceptibilities.

The effect of susceptibility has to be considered when orienting cores by this magnetic method. Since the susceptibility effects vary inversely as the sixth power of the distance between the magnets and the core and the polarity only varies inversely as the third power of this distance, it is possible to eliminate the undesirable effects of susceptibility, by increasing the gap between the magnets and the cores tested and also by making a reverse run with the core sample. By subtracting the reverse curve from the forward curve the effect of susceptibility is practically eliminated, since the susceptibility reacts on the magnets in one direction only.

The instrument used in Polar Core Orientation is shown in Figure 12. Its operation is entirely automatic and self-checking. The operator places the core in the coreholder, puts the room in darkness and throws the switch, which starts the instrument and keeps it in motion until the recording is completed.

The core holder is shown in Figure 12 and the method of recording in Figure 13. A small mirror is attached to the magnet suspension and a small light originating from the recording system is directed at the mirror. This light is reflected by the mirror back to the recording system, the recording drum of which revolves in unison with the core.

The forward run is recorded in solid black, while the reverse run is recorded in dashed line. Due to susceptibility effects, the curves are never true sine curves (see Figure 14) but become nearly true sine curves after plotting the resultant curve (forward less reverse) as may be seen in Figure 15.

The resultant curve is interpreted by measuring an 180 degree segment between the slopes of the curves parallel to the abcissa. The intersection of this segment with the down slope of the curve determines magnetic south.

Since the beginning of the recorded curve represents the point at which the zero line is marked on the core itself, the number of degrees between south and zero point is measured and applied to the core itself.

Corrections for the inclination and direction of the samples actual location, as well as corrections for the magnetic vector of the earth must be made to obtain the true angle and direction of the dip.

Cores with good bedding planes (see Fig. 16) should be selected The samples should preferably be not less than two-inch diameter and three inches long. They must be marked top and bottom correctly, when taken out of the core barrel. They also must never be put in close proximity to any strong electrical or magnetic field.

Final results with all pertinent data are reported on a form as shown in Fig. 17. Cores which have been stored for several years in the core sample room as well as cores shipped from foreign countries over 10,000 miles distant have thus been successfully oriented.

This method avoids loss of drilling time, since it permits the hand picking of samples out of the core tray and chosen for desirable bedding planes and suitable size. The orientation can be made at will and for cores received from any distance.

HYDRAULIC COUPLINGS In Field Applications

By M. T. Archer

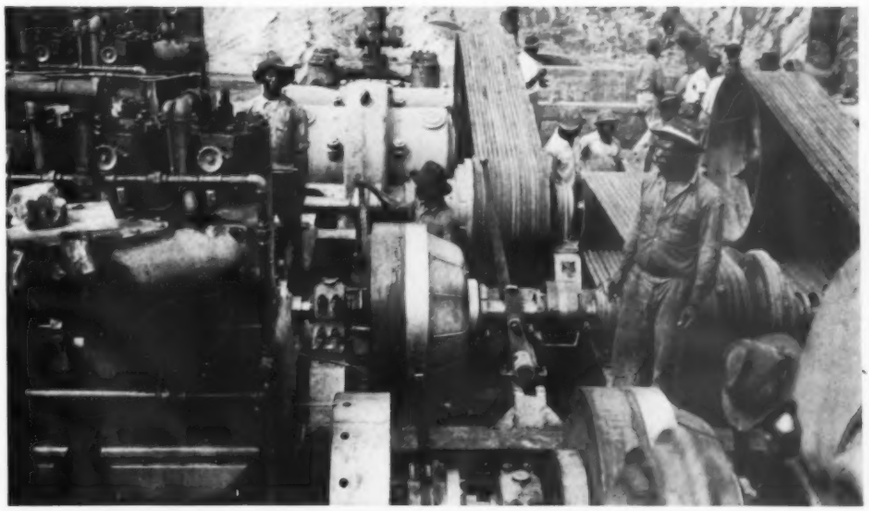
Director of Research,

The National Supply Company

MUCH has been written regarding the operating characteristics and the application of hydraulic couplings. A natural step in their development was the application to rotary drilling rigs. Their introduction to American drilling rigs has been slow but in the Dutch East Indies, Trinidad, and other fields, outside the United States, considerable progress has been made.

The economy of internal combustion engines, especially the Diesel engine, has prompted its use for rig drives in these isolated territories. While such rigs have been entirely successful it was found an advantage, as their size increased, to apply hydraulic couplings between the engines and the drive proper.

The simplest form of hydraulic coupling is the traction type. The nature of rotary drilling, however, imposes the necessity for speed control over a considerable range both at the table and at the slush pumps. Such control can best be secured by using the variable speed couplings, preferably the recently introduced scoop control type.



A field application of the hydraulic coupling in Trinidad.

As depth increases it is necessary to reduce the volume handled by the power slush pump in order to avoid overloading. The characteristics of internal combustion engines permit safe maximum torque limits and the engine slows down when overloaded. Eventually,

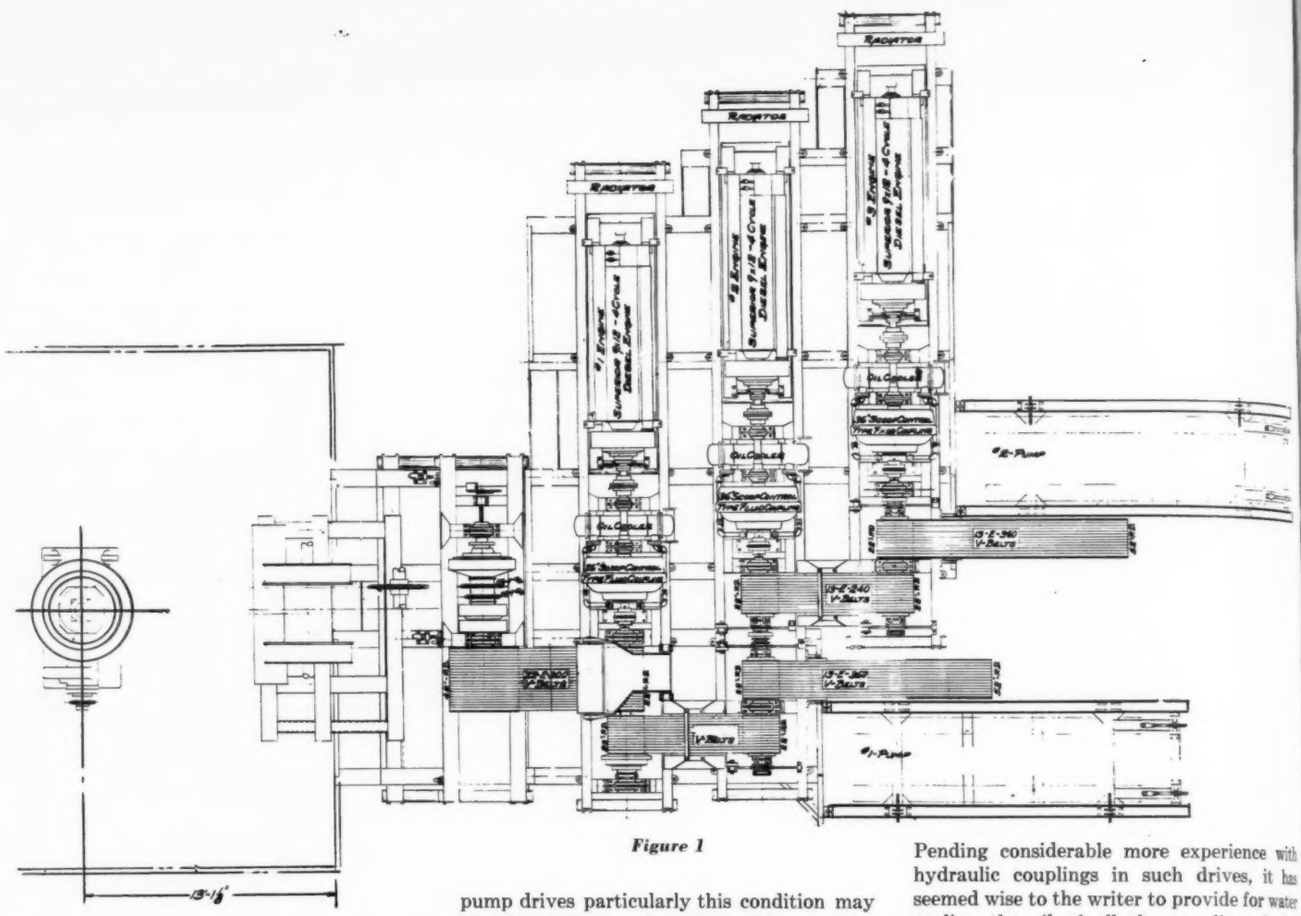


Figure 1

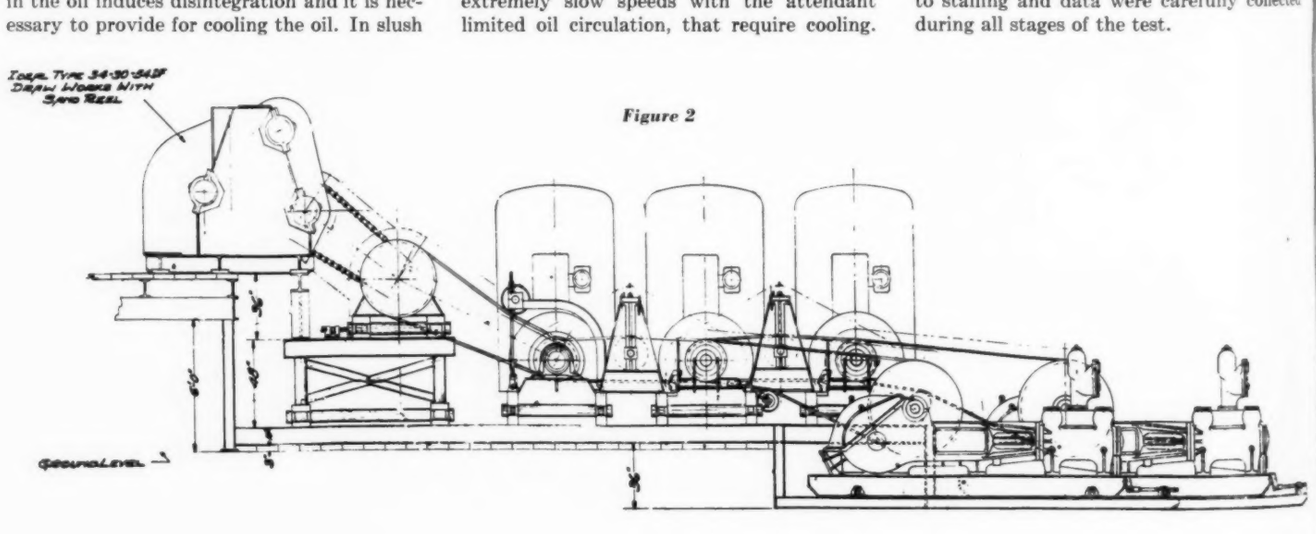
such overloading will stall the engine or necessitate its disconnection from the circuit. With the hydraulic coupling inserted between the engine and the load, however, the slip of the coupling automatically increases faster than the engine speed decreases and at a predetermined point, within the satisfactory speed range of the engine, the coupling can slip 100 percent without further overloading the engine.

The coupling will naturally dissipate by convection approximately seven to 10 percent slip without the oil becoming dangerously heated. Beyond this point the heat generated in the oil induces disintegration and it is necessary to provide for cooling the oil. In slush pump drives particularly this condition may occur frequently and water cooling, or some other method of cooling the oil, must be provided in the assembly.

When hoisting, the instantaneous load is severe and the slip of the coupling may be temporarily great but the short hoisting cycle is followed immediately by an idling cycle which permits cooling sufficient to offset the overload heating. For hoisting alone, therefore, it is hardly necessary to introduce auxiliary cooling. It happens, however, that the No. 1 engine, which is always in the hoisting circuit, is also used for operating the rotary table and there are occasions when fishing, or when operating the table at extremely slow speeds with the attendant limited oil circulation, that require cooling. Pending considerable more experience with hydraulic couplings in such drives, it has seemed wise to the writer to provide for water cooling the oil of all the couplings in the hookup.

The National Supply Company, and its British connection, Oil Well Engineering Company, Limited, became interested in these hydraulic couplings above five years ago. After considerable study two 36 in. ring valve couplings were secured and installed in a test arrangement with a Diesel engine at National's Springfield, Ohio, plant. This hookup consisted of a nine inch by 12 in., eight-cylinder, 600 r.p.m. full Diesel engine, driving through a 36 in. coupling to a 350 h.p. power pump. The power pump was operated at all speeds from maximum down to stalling and data were carefully collected during all stages of the test.

Figure 2



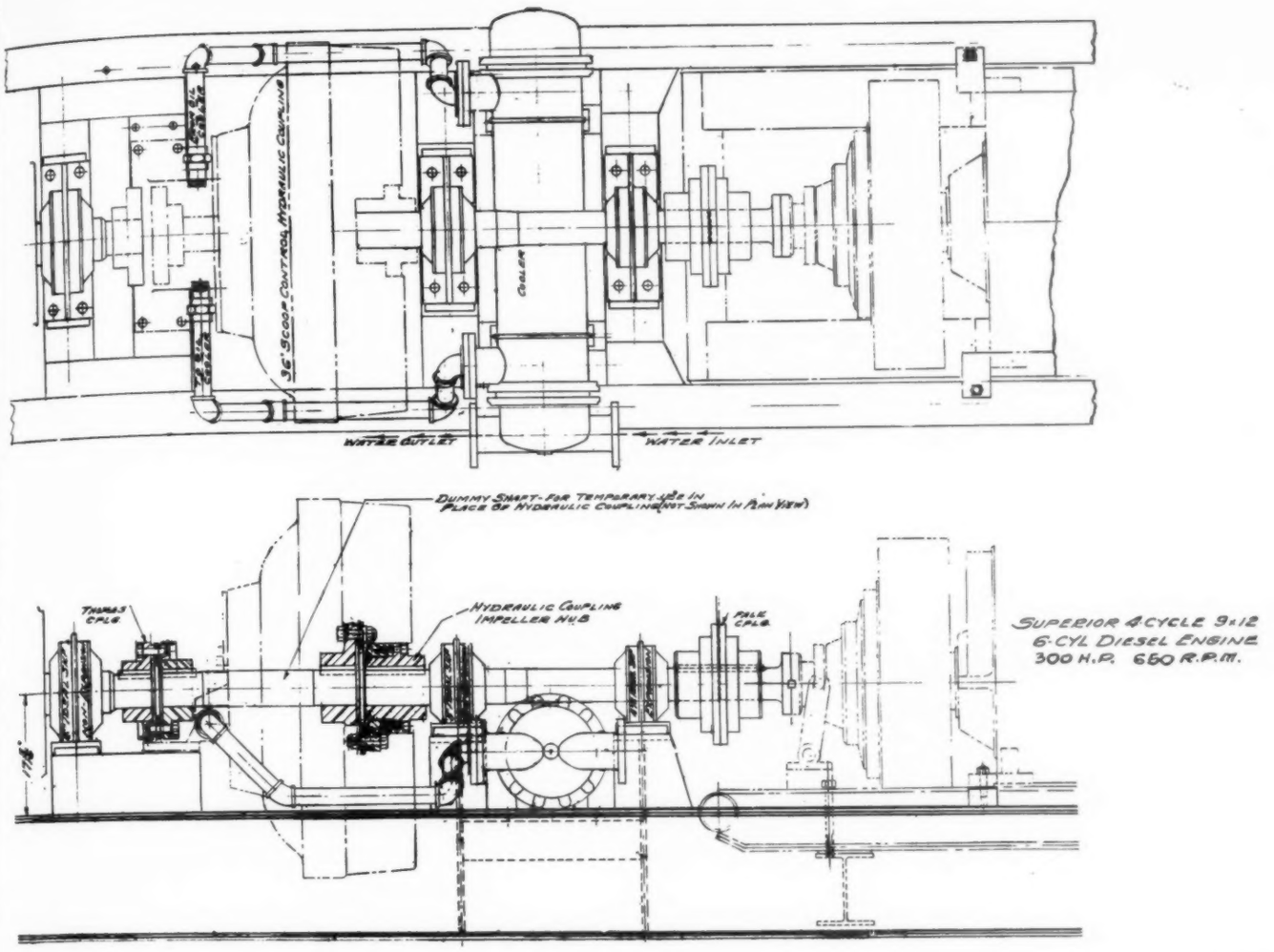

36" SCOOP CONTROL HYDRAULIC COUPLING
WATER OUTLET
WATER INLET
DUMMY SHAFT - FOR TEMPORARY USE IN PLACE OF HYDRAULIC COUPLING (NOT SHOWN IN PLAN VIEW)
THRUST CPLG.
HYDRAULIC COUPLING IMPELLER HUB
FALK CPLG.
SUPERIOR 4 CYCLE 9x12 6-CYL DIESEL ENGINE 300 H.P. 650 R.P.M.

Figure 3

During these tests the large power pump was repeatedly operated in a stalled condition for several hours at a time. The couplings were provided with a scoop controlled water jacket developed in preliminary tests and it was found that this provided for completely stalled operation without heating the oil beyond an entirely satisfactory temperature. As a result of these tests the couplings and engines involved were built into a rotary drive rig for Trinidad. This rig has been operating for the past two years and has drilled two deep tests, one to 10,000 ft.The performance has been very satisfactory and the Trinidad operators have found that the great flexibility available with their coupling drives permits handling situations easily which would have been difficult with the conventional drives.

The usual internal combustion rig involves two engines, both of which are operated to the hoist when coming out of the hole and then divided, one engine to the rotary and one engine to the pump, when drilling. National has made a great many such rigs, both for domestic and export duty and they have been entirely satisfactory.

In the export field, however, reserve power in a still more flexible hookup is desirable. Also, the transportation difficulties in some export fields, warrant obtaining the maximum desired power with the least possible weight and smallest feasible space. To meet such conditions National developed the three-engine arrangement shown in the attached sketches.

This three-engine arrangement permits two engines for hoisting while one can be in reserve for running a mud-mixing pump or for other duties. When drilling, No. 1 engine can operate the table, while No. 2 engine is free to drive one power pump and No. 3 engine the other. With the proper pump hookup this also permits the operation of these power pumps in parallel, or in series for the harder drilling.

It will be noted particularly, that the arrangement of the pump drives permit each pump to operate separately at any desired speed and to be connected up in series or in parallel as required. For routine drilling there is always a pump in reserve. Also all three engines can be used in an emergency with either draw works or pumps. With the conventional method of driving both pumps from the same countershaft this flexibility is not obtainable. The common countershaft does not permit the selective speeds required to operate the power pumps in compounded hookup. Neither does it permit interchanging engines to any part of the drive, a feature perfectly simple with the three-engine hookup.

For purposes of economy the initial hydraulic coupling drive for Trinidad included only two couplings in the three-engine hookup. Engines No. 1 and No. 2 were provided with couplings so that both could be run in synchronization when hoisting. Engine No. 2 could also run No. 1 pump while drilling. Engine No. 3 drove No. 2 pump without the benefit of the hydraulic coupling. During normal operation, when only one pump is required, either pump could be operated, but when operating the pumps in compound, which was done frequently, the single hydraulic coupling in the pump drive proved its value.

As is well known, the delivery characteristics of duplex power pumps render it undesirable, if not impractical, to operate them in series. When this is necessary with direct engine drives a properly controlled air chamber system should be interposed between No. 1 and No. 2 pump. Such complications have discouraged the compounding of power pumps though such practice is common with direct acting steam pumps.

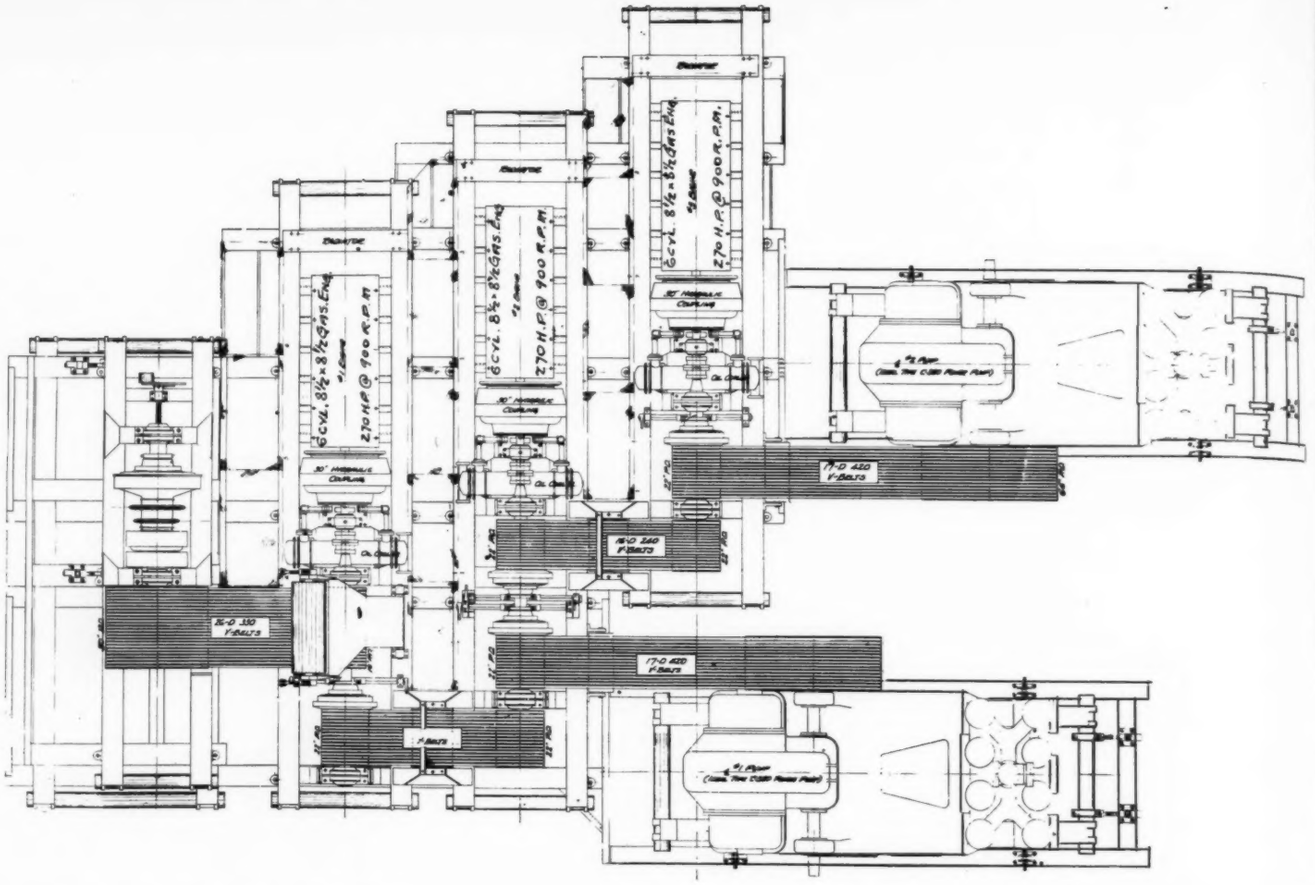


Figure 4

The flexibility and the slip characteristics of the hydraulic coupling make compounding of power pumps feasible. Without the benefit of any interposed air chambers between the pumps, Trinidad operators ran the two power pumps in series for a long period. No. 2 engine with the hydraulic coupling drive, operated No. 1 pump at a speed which would nominally give a greater fluid volume than would be required by No. 2 pump at its operating speed. The automatic slip characteristics of the coupling permitted No. 1 pump delivery to vary in approximate phase with that of No. 2.

Also in Trinidad, after setting nine inch casing at 6,500 ft. and cementing, it was desired to test the casing before proceeding with drilling. This was accomplished by merely turning the No. 2 pump, driven through the hydraulic coupling, into the casing and closing the outlet gate valve. The pump stalled while the engine continued to run at approximately half-speed and maintained the pressure on the casing of 1,250 lbs. On another occasion when No. 1 engine was operating the table during a fishing job, the rotating speed of the table was reduced to approximately seven revolutions per minute by operating the ring valve and regulating the engine speed. During this time the engine was not slowed down more than 50 percent of its maximum speed.

On fishing jobs the hydraulic couplings have proved a great help and permit efficiency in manipulating the fishing tools. Trinidad used a special overshot which operates by pump pressure. Maintaining certain pressures, since the overshot does not permit circulation, means that the power pump is stalled. This overshot was operated for three hours with coupling and pump stalled while pressure was varied from 200 lbs. to 1,200 lbs., by manipulating the ring valve and the engine speed. Performance was entirely satisfactory. Subsequent to the Trinidad installation, National prepared several large rig drives for other foreign fields incorporating hydraulic couplings. The three-engine hookup was maintained throughout these assemblies. Figure No. 1 shows the plan view of one of these rigs. Figure No. 2 shows the elevation of same.

Maximum power was required with these rigs to permit 10,000 ft. drilling. This necessitated a fairly large and heavy engine. The specifications required that the engine be removable from the main assembly and transported separately in the field. This in turn required separate skid assembly for the engine which had to be arranged so as to be readily inserted in the main frame at destination and be capable of rapid assembly and perfect alignment. Figure No. 3, shows how this was accomplished.

To permit separate transportation and reassembly of the engine it was mounted on its own skids which were in turn supported on submerged cross members in the main skids. The coupling was divorced from the engine and assembled on a separate set of bearings as shown. Connection was made between the engine and the hydraulic coupling supporting shaft by means of a Falk coupling. Connection at the outlet side of the coupling to the countershaft was made through a Thomas coupling. It will be seen, therefore, that the countershaft is one assembly and the hydraulic coupling is a second separate assembly, while the engine is still another separate assembly. There is no possible danger of misalignment in the assembly and the coupling can be left connected with the countershaft and moved with the main skids without disturbing its setup.

Another assembly utilizes a 30 in. coupling mounted on a 900 r.p.m. engine of approximately the same capacity. This job is intended for work in the United States and since there is no transportation problem involved, the engine is left permanently assembled on the main skids. Taking advantage of this fact space and weight was saved by attaching the coupling directly to the engine flywheel. The cooling system is integrally mounted on the skids and is thus a permanent part of the installation. A complete control system for operating the scoop tube of the hydraulic coupling is provided at the driller's position on the derrick floor.

These two rigs represent the two arrangements which will probably govern future installations of this capacity. When necessary to remove or transport the engine separately,

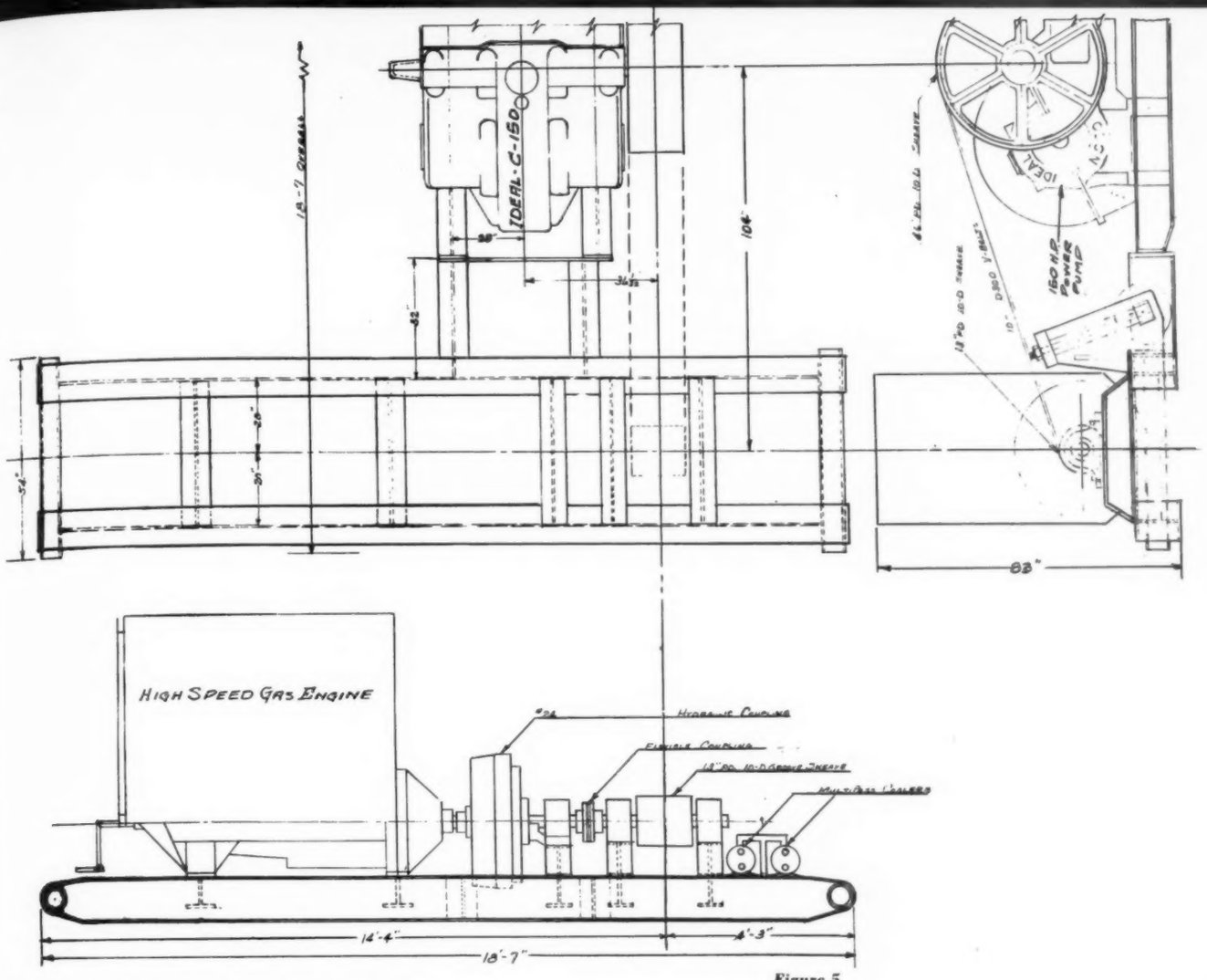


Figure 5

as is required for certain export jobs, the arrangement shown in Figures 1 to 3 will prevail. In the United States, or in localities where transportation is not a problem, the engine can be installed permanently on the main skids. This in turn permits mounting the hydraulic coupling close to, or attached to, the engine flywheel and thus saves space and weight.

Figure 5 illustrates a separate power slush pump drive. This is the internal combustion engine having a hydraulic coupling mounted on the power take off shaft of a high speed gas engine. The whole assembly is in turn mounted integrally on a skid which is attached in the field to the pump skids. Provision is made for adjusting the belt tension.

The coupling on Figure 5 is a scoop controlled coupling arranged for water cooling. Its use allows for a great improvement in the pump operation at a nominal expense.

A similar separate pump drive with a squirrel cage motor and a scoop controlled coupling has been arranged. This permits for complete variable control of the pump speed down to stalling. The cooling system allows for operation at full torque over protracted periods. There are many cases where such separate pump drives will prove desirable and it is felt that their use will increase.

An essential point in the hydraulic coupling power pump arrangement is that the torque output from the coupling equals the torque input. For internal combustion engines, therefore, the hydraulic coupling is a natural application since the increase in torque with decrease in speed of such engines is only nominal. Once the drive is selected which operates at the correct capacity for both pump and engine, there is no danger of overloading the pump since at no time is there any increase in torque beyond that put out by the engine.

The use of the hydraulic coupling in a motor driven assembly permits using a squirrel cage motor with considerable saving on the electrical equipment. However, such motors fall off little in speed with increase in torque and their characteristics permit a heavy overload on the pump unless provision is taken to control the input current to the motor. For such drives, a control arrangement includes a system of relays operated by the applied motor current. After the predetermined maximum allowable current is reached in the motor circuit, the relay starts a small geared motor which controls the lever of the scoop tube. This withdraws the scoop from the reservoir and reduces the quantity of oil in the coupling circuit, thus maintaining an approximately constant torque input.

Fluid Couplings Tested In Netherland India

FOUR heavy Diesel drilling outfits making use of the fluid coupling principle described in the article on page 86 have actually been in use under the rigorous conditions to be found in the jungles of Netherland India. These outfits consist of a countershaft with forward and reverse clutch driven by a 240 h.p.-800 r.p.m. Diesel engine connected to the drawworks and a countershaft with pulleys and clutches for driving the pumps which are powered by a second 240 h.p. Diesel. Both countershafts are connected with a shaft with flexible couplings making it possible to drive the draw works and pumps with either or with both of the two engines.

Despite the fact that this hook-up has developed sufficient power to complete wells at depths of 10,000 ft. in actual practice in the East Indies, the company that has been using

(Continued on page 110)

FLUID COUPLING

Applied to Rotary Drilling Equipment

By G. Vivian Davies, A.M.I. Mech. E., M. Inst. Pet., F. C. S.

English Practice in its Adaptation Extends Use of Electric Drive in Oil Well Drilling and Enables Diesel Rig to Equal Performance of Steam Unit.

SINCE the first Diesel driven rig was erected in California in 1924, there has been a steady increase in the employment of the Diesel engine, and more recently the gas engine, where supplies of natural gas are available in sufficient quantity, as a prime mover for oil-well drilling.

This type of power unit has the great advantage over a steam installation that no cumbersome boiler plant with lengthy steam lines need be set up and taken down when the well is completed or abandoned, while the difficulty of providing an adequate supply of suitable boiler feed water in outlying districts is obviated.

In drilling there are three distinct power requirements, which are as follows: a variable speed control for the slush pumps; a variable speed for the rotary drilling table; a heavy power demand for hoisting operations.

The steam engine with its great flexibility of control and automatic stalling at full load, fulfills these requirements admirably. Internal combustion engines do not, because of their inability to handle shock loads and their limitation in torque characteristics. Consequently D. C. electric units were introduced as transmission media with the Ward Leonard system of control, necessitating a separate generator for each motor with consequent increase in cost and complication.

Other objections in the past to the use of such prime movers have been the difficulty of designing suitable clutches, and providing an effective means of reversing the rotary draw works. Special friction clutches, right- and left-hand engines, and three-speed power transmission coupled to four-speed draw works giving a total of 12 speeds, have all been utilized with varying degree of success.

The introduction of the Vulcan Sinclair fluid coupling, which is being used at present by European oil companies has enabled most of these disadvantages to be overcome, because it provides the following essential characteristics; a practically complete connection and disconnection of the drive with a continuously running engine: a perfect cushioning medium, since power is transmitted by virtue of the kinetic energy of the oil circulating in the coupling, thus damping out torsional vibrations from the engine and absorbing shock loads from the driven machinery, a completely smooth take-up simply by accelerating the engine and allowing the load to be picked up gradually while running; an ability to transmit power equally well in either direction, thus overcoming the difficulty of reversing; an absence of moving parts subject to wear and consequent replacement, with a degree of simplicity and low initial cost which are remarkable; and a positive safeguard against stalling of the prime mover by overload while transmitting the designed overload torque to the driven shaft.

The remarkably effective cushioning action is well illustrated by the following Torsiographs, which were taken on a six-cylinder engine of 550 b.h.p. at 450 r.p.m. connected to a fluid coupling on the same shaft as a Froude brake. Measurements were taken on the input and output shafts respectively and are shown in Figure 1. It will be noted that the slip in one case is three percent and in the other only 2.9 percent.

Although the fluid coupling is a simple piece of apparatus in itself, and its operation depends entirely on the centrifugal force of a column of liquid, a thorough understanding of it presents difficulty to many people, with the result that booklets have been published explaining it in simplified terms. For the sake of brevity only a simplified analysis of its operation as shown in Figure 2 will be given. The fluid coupling consists essentially of two elements, a primary member attached to the input or driving shaft and a secondary member attached to the output or driven shaft. Figure 3 shows a section of a traction type coupling, which is the simplest form, and also an outside view of the same.

Both the primary member or impeller and the secondary member or runner are provided with radial vanes dividing an annular ring, which is approximately elliptical in cross section, into compartments. In the center of this ring there is an annular core, which is integral one-half with the impeller and the other half with the runner.

The fluid with which the coupling is filled—usually oil—is driven outwards by centrifugal force and as the runner always rotates at a slower speed than the impeller, the difference in centrifugal force causes the fluid to circulate around the annular core and thus act as an energy transmission medium.

The difference in speed of rotation expressed as a percentage of the speed of the driving member is termed the slip, and is referred to in Figure 1. When the coupling is completely filled the energy transmitted by the impeller at a certain speed or rotation is within limits approximately proportional to the slip. In considering this, it should be borne in mind that under all conditions of slip and speed the torque at the output shaft is equal to the torque at the input shaft. There is no loss of torque through the coupling.

Three types of coupling have been developed and are now on the market. The traction type is used with constant filling of oil, usually in connection with variable speed engines or motors. The ring valve type, also used with constant filling of oil, but incorporating a ring valve for regulating the degree of slip. The scoop tube control type is designed for variable speed drives from variable speed engines or constant speed motors. Close speed regulation obtained by varying the quantity of oil in the working circuit.

SCOOP TUBE COUPLING

This was first introduced in 1930 and since then over 2,000 such couplings have been put into service, transmitting upwards of 250,000 hp., varying from units of three to 2,000 hp. in different industries. It differs from the traction type in that it provides a means of speed regulation and also makes possible the declutching of the driving from the driven shaft without the use of a friction clutch.

The scoop control coupling, a more recent development of the scoop tube type, is shown in section in Figure 4.

As in other types of fluid couplings the impeller is mounted on the input shaft, but an inner casing with a series of leak-off nozzles through which the oil continually flows to the reservoir when operating, and a reservoir casing are both bolted onto the impeller itself.

The runner is carried on the output shaft, but is located axially by a tie rod thrust bearing which takes care of any hydraulic thrust.

The scoop tube which regulates the quantity of fluid in the working circuit and hence the speed, is mounted eccentrically on a housing bolted to the stationery bracket, and can be rocked through an angle of about 70 deg. so that the tip is clear of the rotating annulus of fluid in the withdrawn position and the working circuit empty.

The position of the scoop tube can be adjusted by hand or remote control, and automatic control can be readily applied. There is a continuous circulation through the scoop tube and cooler back to the working circuit as shown by the arrows in Figure 4 when this is provided, hence any given position of the scoop determines the quantity of fluid in the working circuit and thus the speed of the output shaft. When a cooler is provided, connec-

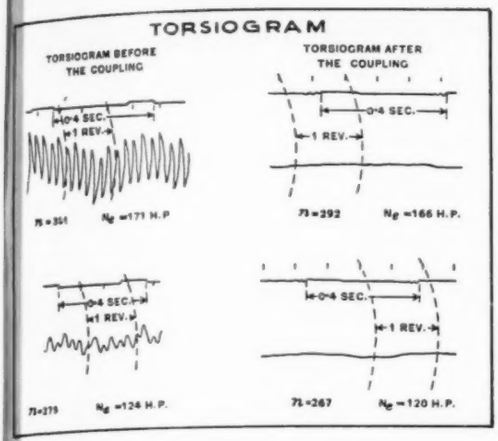


Figure 1

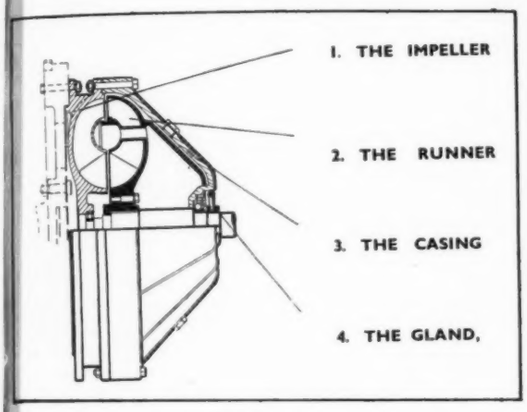
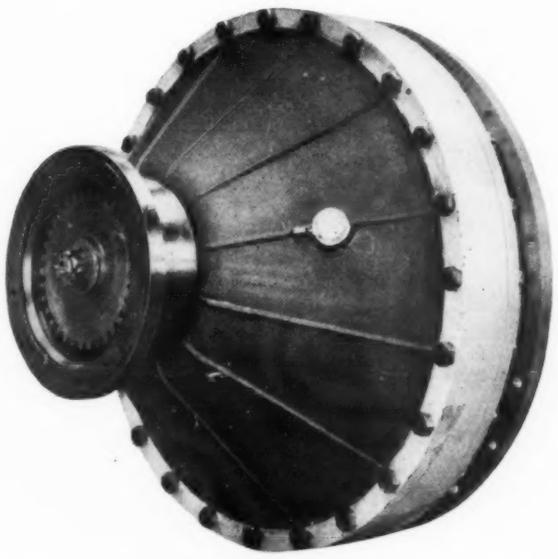


Figure 3

Figure 2



tion is made to the inlet and outlet flanges on the fixed bracket by means of suitable piping.

A flexible coupling for taking the drive from the output shaft is standardized. This, in conjunction with the self-aligning bearing support of the runner shaft caters for angular misalignment and allows the shaft to act as a cardan drive. Where mal-alignment may arise due to settling of foundations, distortion of bed-plates, etc., conditions not infrequently encountered in oilfield work, this is a practical feature of great importance.

Figure 7 illustrates typical torque speed and slip speed curves for the scoop tube coupling, with the scoop in the engaged position, demonstrating its remarkable flexibility.

In addition to the general features of fluid couplings mentioned, the scoop tube coupling possesses the additional advantages that infinitely variable speed regulation can be obtained over a range of five to one. In one test with ring valve coupling the speed of a rotary table was cut down from 100 r.p.m. to six r.p.m. by reducing the engine speed from 600 to 200 r.p.m. as a result of operating the control. The same results can be obtained in the reverse direction by the use of a double-ended scoop, and reversing engine. The scoop tube control can be interconnected with the engine fuel control, and thus made automatic, while at the same time retaining the manual control as a standby. The output shaft can be inched easily under full load because the scoop tube control is very sensitive and the drive take-up extremely smooth.

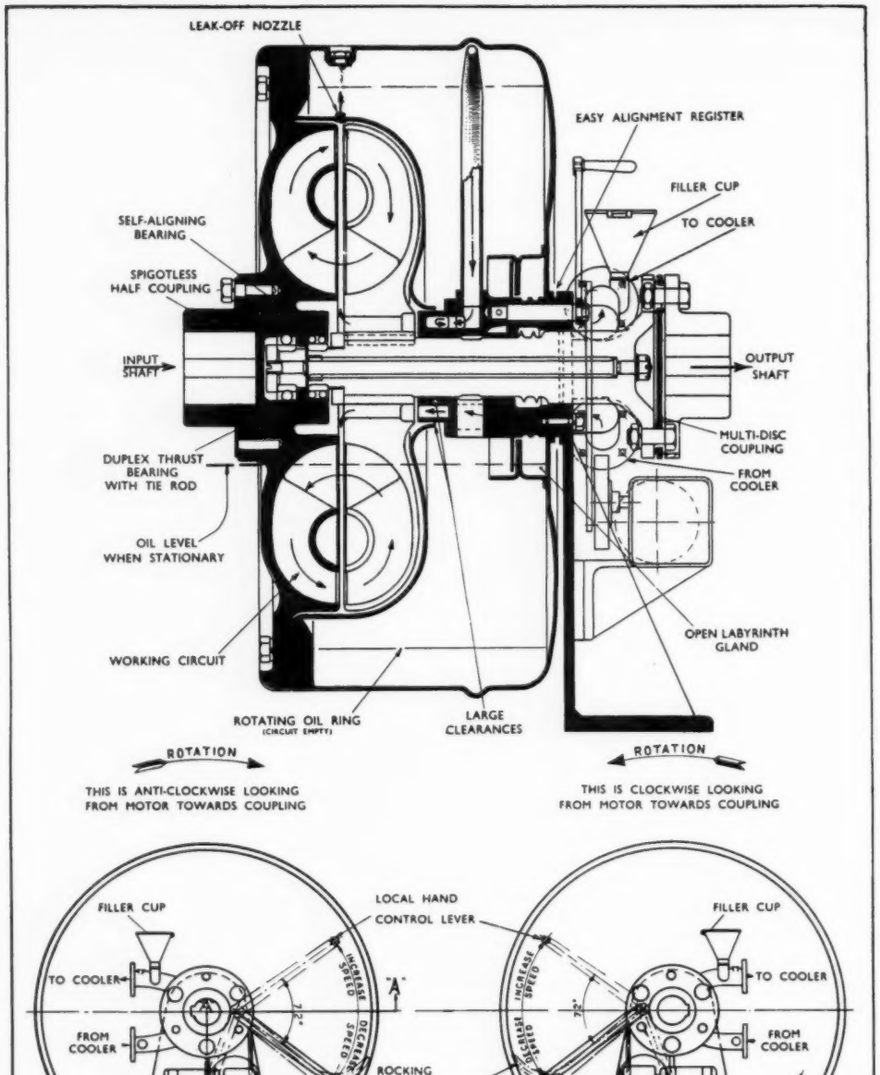


Figure 4

An impulse or momentum start can be applied by closing the scoop tube control, running the engine up to speed, and then opening the control. In this way a substantial overload torque can be applied for freeing an obstruction.

The above advantages are particularly valuable in the case of rotary drilling, especially the ability to inch the rotary table and apply momentum impulses.

Owing to rotation in contact with the air, the self-cooling capacity of the fluid coupling is 10 to 20 times that of an equivalent stationary body, and is ample for most applications. Cooling equipment is usually provided if the operating temperature continuously exceeds 180 to 200 deg. F., but experience has shown that self-cooled couplings can operate safely for short periods at temperatures as high as 240 to 260 deg. F.

Oil is the fluid used and generally speaking a good grade of light turbine oil having good resistance to oxidation and sludging is very suitable. A normal life of 4,000 to 6,000 hours can be expected, and if the operating temperature is below 180 deg. F. this life will be greatly exceeded.

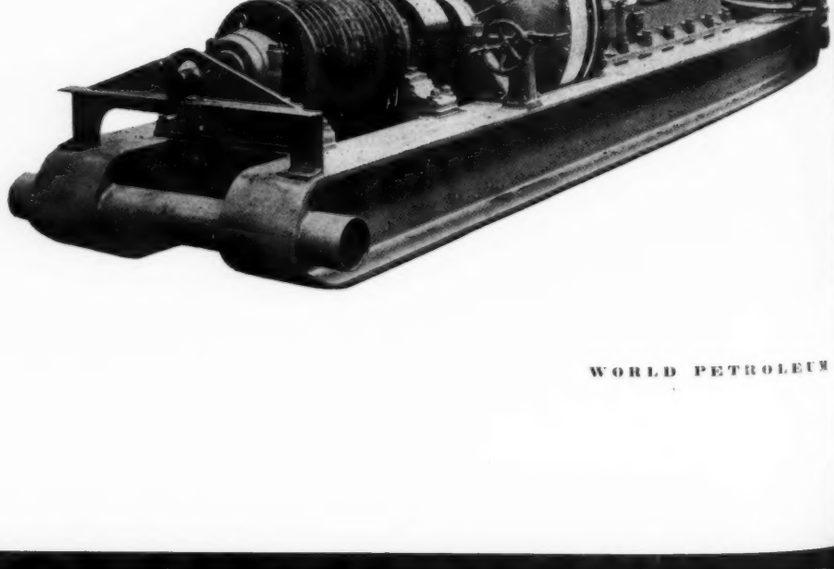
ELECTRIC DRIVES

The disadvantages of the direct coupled A.C. motor as regards starting against heavy load, stalling and overload, have restricted the use of electric drives in oilwell drilling. The introduction of the fluid coupling, however, opens up the field afresh as stalling can be made automatic and the load can be taken up gradually. Synchronous motors can be used for driving the slush pumps, and a slip ring motor with controller for driving the draw works.

APPLICATION

When using internal combustion engines for oilwell drilling, two engines are used and are so arranged that either can drive the draw works or slush pumps, while both engines can be compounded for heavy hoisting operations. Sometimes a third engine is set up in such a way that it can assist either of the other two and also act as a standby. If this latter arrangement is adopted, the individual engines can be of smaller output than is the case where two only are used. Figure 6 illustrates a proposed arrangement using three engines with V-belt drives, set up so that any one

Figure 5



engine can drive pumps or draw works through fluid couplings. A simple reversing drive is thus obtained without the use of friction clutches or reversing engines.

In such set-ups it has been the practice to use a main friction clutch incorporated in a forward and reverse gear between the engine and draw works, by which the drive can be interrupted to engage or disengage the various dog clutches. The engine runs at the governed full speed and the driller uses forward and reverse friction control for manipulation in the same way as the forward and reverse control of the conventional steam engine. The duty thrown on the friction clutches is consequently heavy and the reversing gear has to be of exceptionally robust construction. When the main drive is taken through a fluid coupling the work on the friction clutches is much reduced and it is not possible to start the engine or apply an excessive overload to the gear. Friction clutches are eliminated altogether in the layout of Figure 6.

The use of the fluid coupling gives to the internal combustion engine the ability of the steam engine automatically to stall under excess pressure such as may occur with a plugged bit and to maintain such pressure during the time the blockage is being cleared.

Use of fluid couplings in connection with drilling has now become established practice with many European oil companies; one recently placed orders for over 20 sets. The engines this company are using are 240 h.p. at 800 r.p.m., the fuel consumption varying from 174 gr. at full load and full speed to 164 gr. at half load and half speed. Two engines are used and are grouped through a common countershaft, the drive being taken through V-type belts. An engine hook-up of this type is illustrated in Figure 5.

The fluid coupling replaces for the greater part the conventional flywheel, which is thus of small dimensions. The engine, cooling arrangements, fluid coupling (ring valve traction type) and V-belt pulley are all mounted on a single bedplate giving good rigidity and alignment.

During the operational period of 14,268 working hours, or approximately 19 months, the installation worked with complete satisfaction.

Every manipulation which can be carried out with a steam rig could also be carried out with the Diesel unit. Pulling times of drill pipe compared favorably with those of the steam rig, while the drilling and coring speeds showed no noticeable difference. However, the water consumption was 120 cu. m. a day against 250 cu.m. a day for a similar steam rig, while the Diesel installation proved to be 25,000 kg. lighter than the steam rig.

The fluid coupling should permit the introduction of several interesting developments in drilling, two of which will be mentioned as they are practical propositions. The first is the use of a direct reversing Diesel engine with an ordinary marine control. Employing a double-ended scoop tube coupling, very little compressed air would be needed for the reversing operation. The second is the use of a traction type gear box with pre-selective

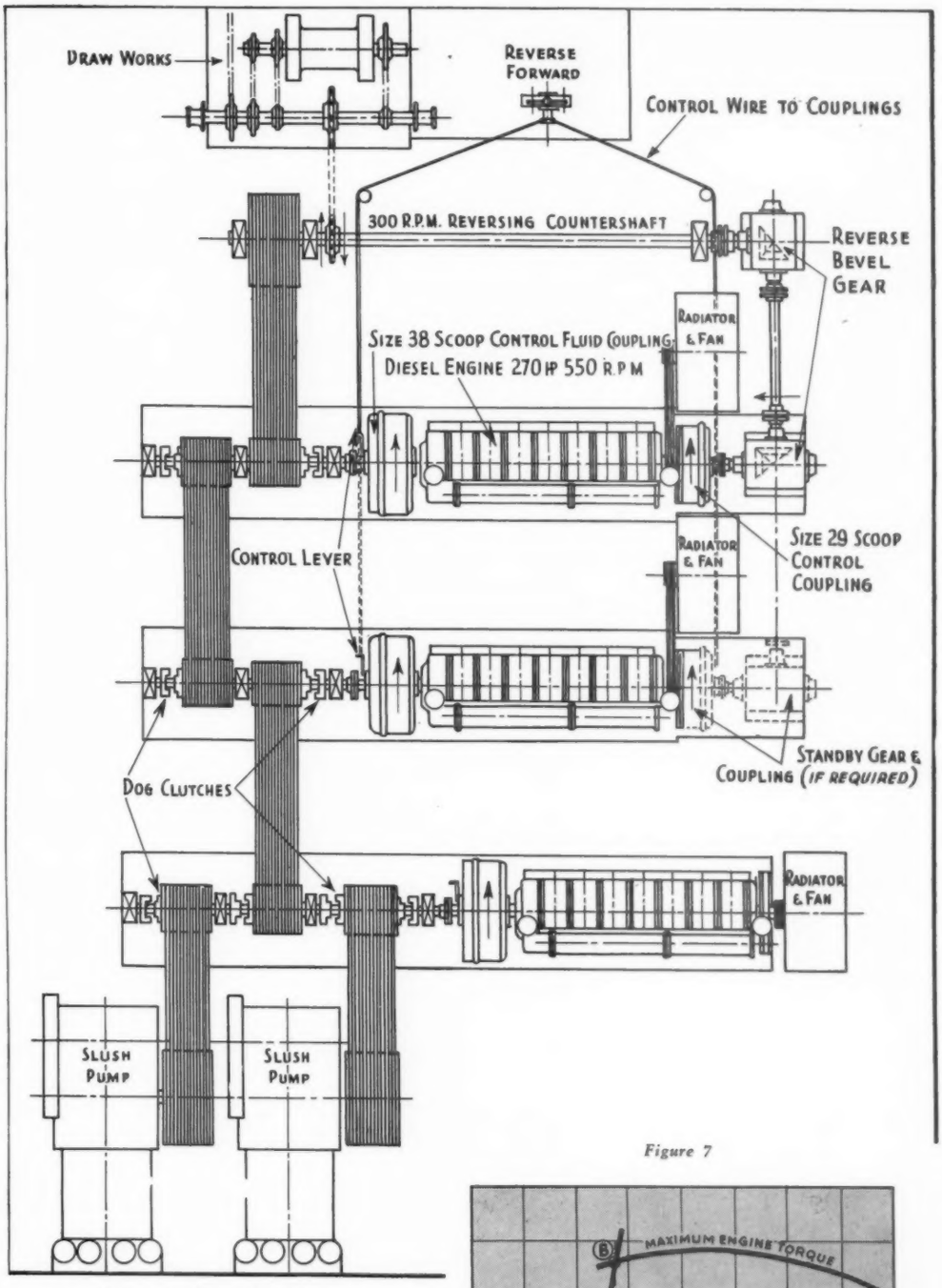
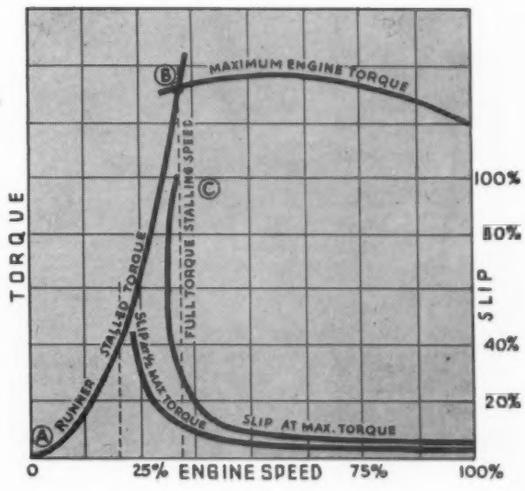


Figure 6—Alternative drives for slush pumps and draw works, incorporating fluid coupling drive and reversing countershaft.

control similar to that developed for Diesel locomotives. The employment of this would enable the design of the conventional drawworks with its clash dog clutches and sloppy driving chains to be simplified and improved.

The author would like to acknowledge gratefully the assistance he has received from Hydraulic Coupling and Engineering Co., Ltd., of Isleworth, London, and from the papers read at the Second World Petroleum Congress by Messrs. Hohmann and Dawson

Figure 7



Foreign Oil Legion

GUY STEVENS, a director of Kuwait Oil Co., Ltd., and representative of Gulf Oil Corporation's interests in Europe returned to the United States early in June. For the past year Mr. Stevens has been actively engaged in the direction of exploratory work conducted in Denmark by the Danish American Oil Co., subsidiary of Gulf. Following the German occupation of Denmark drilling activities have been temporarily suspended and the group of Americans engaged in this work has been withdrawn.

FREDRICK J. WOLFE, chairman of Anglo American Oil Company, Ltd., retired from his position as executive head of the company in June and will make his home in the United States.

C. STACEY ADAMS of Paris, European representative of Sinclair, returned to New York early in June and with his family will spend the summer in the United States. Mr. Adams at present is on a tour of the Mid-Continent.

C. ZULVER, for many years head of the marine department of Shell with headquarters in London, retired last month. Mr. Zulver was recognized as a leading authority on shipping matters and was responsible for numerous improvements in tanker design and equipment.

Cosmo-Sileo

Guy Stevens photographed on arrival in New York harbor early in June

WILLIAM H. BERG, president of the Standard Oil Company of California died in Burlingame, California, on June 26th, as a result of a heart attack at the age of 58. Mr. Berg was born in Tripoli, Iowa and entered the production department of California Standard in 1908. He was appointed general manager of the foreign crude oil producing department in 1921, vice president of the company in 1927 and president in 1937.

William H. Berg

VEZIO CAMBI, vice president and general manager of the Societa Petrolifera Italiana, with offices and refinery at Fornovo Taro (Parma), Italy, died on the evening of June 8, in New York City after a short illness. Mr. Cambi came to the United States in May and was planning to make a trip to the Mid-Continent and Gulf oilfields when he suffered a heart attack.

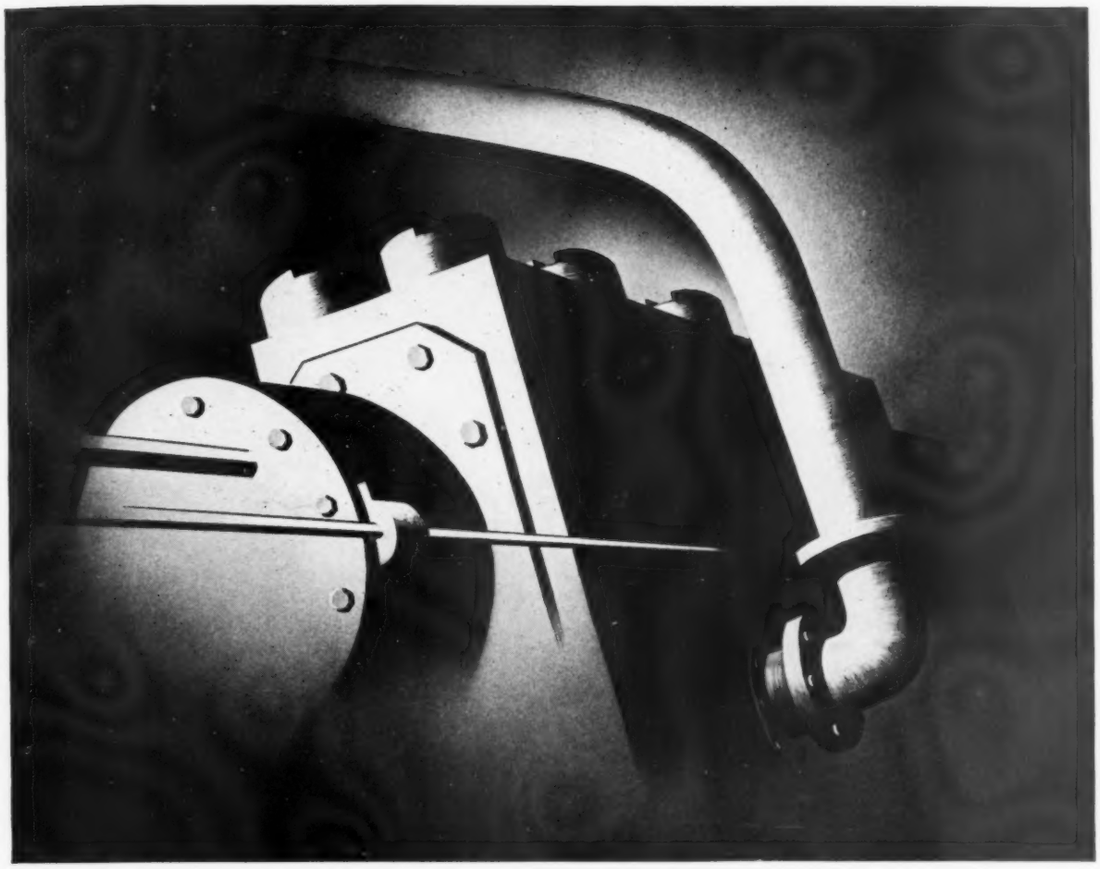
Two new members were elected to the Board of Directors of Standard Oil Co. (NJ) at the annual meeting early in June. These were Eugene Holman, who for the past several years has been President of Creole Petroleum Corporation and Lago Petroleum Corporation, and F. W. Abrams, who has been the chief executive officer of Standard Oil Company of New Jersey since 1933.

Both of these men have been long connected with the Standard organization.

(Continued on page 92)

Eugene Holman

© Blank & Stoller



THE TOUGHER THE BETTER

Modern materials show up to best advantage when operating conditions are really bad. It's on the mean jobs that they fully demonstrate what they can do in keeping replacement and maintenance costs down and general machine efficiency up.

Take the plungers on hot oil pumps, for example. The conditions are plenty tough — 700 degree F. temperature, 1000 pounds pressure plus abrasion and corrosion.

Yet plungers of Molybdenum iron, a comparatively inexpensive material, are standing up in this exacting service and cutting replacement costs. The iron retains its hardness and abrasion resistance at the high temperature involved. Re-grinding and polishing to restore the finish after long periods of service is the only maintenance required.

Molybdenum irons are meeting many tough assignments. You will find our technical booklet about them helpful and informative. It is free on request. Ask for "Molybdenum in Cast Iron."

PRODUCERS OF MOLYBDENUM BRIQUETTES, FERRO-MOLYBDENUM, AND CALCIUM MOLYBDATE

Climax Mo-lyb-den-um Company
500 Fifth Avenue · New York City

MOLY

Foreign Oil Legion

(Continued from page 90)

After service in the U. S. Army Air Corps during the first world war Mr. Holman, who had been educated as a geologist and was a graduate of the University of Texas, was with the U. S. Geological Survey for a short time and in 1919 entered the employ of Humble Oil & Refining Company. In 1925 he became chief geologist and in 1929 left the Humble to become assistant to E. J. Sadler then vice-president of the Standard, at 26 Broadway.

Mr. Holman's activities with the parent Standard company have been mainly on the production side. He has been closely identified with production in Venezuela during the period of rapid expansion in Lago and Creole operations and more recently has dealt also with production in several other foreign fields.

Mr. Abrams joined Standard Oil Company of New Jersey in 1912, shortly after his graduation from Syracuse University. His first job was that of draftsman in the company's Eagle Works in Jersey City. From this humble position he rose to be superintendent and then manager of the plant. In 1926 he became general manager of the company's three refineries in New Jersey and in 1927 he became a director. In 1933, on the retirement of C. G. Black, he was elected president of the company.

Frank W. Abrams

C. H. Lieb

Mr. Holman is succeeded as president of Creole by C. H. Lieb who has been vice president. He formerly was president of Carter Oil Company. In succession to Mr. Abrams, Chester F. Smith, formerly vice president of Standard Oil Company of New Jersey, will become president.

G. Harrison Sluith, president of Imperial Oil Ltd. has resigned from the board of Standard Oil Co. (NJ) to devote all his time to the affairs of the Canadian company of which he is the head.

Chester F. Smith

DR. ROBERT E. WILSON, President of Pan American Petroleum and Transport Company, has been designated adviser on petroleum matters to the National Defense Advisory Commission. Dr. Wilson will serve as a special assistant to Edward R. Stettinius in planning the coordination of petroleum operations with the requirements of national defense under the armament program now being launched from Washington. Dr. Wilson has won distinction in both the technical and executive fields of oil industry activities. Following his graduation from Wooster College and advanced engineering study at Massachusetts Institute of Technology, he spent several years in research work and in 1922 was appointed assistant director of research of the Standard Oil Company of Indiana. Subsequently he became assistant to the vice president in charge of manufacture, and later was made a vice president and director. In 1935 he was elected vice chairman of Pan American Petroleum and Transport Company, affiliated with Standard of Indiana and shortly afterward succeeded to the presidency. In 1940 he was the recipient of the official medal of the Society of Chemical Industry which is awarded annually for outstanding achievement in the application of chemical research to industry.

World Wide Drilling

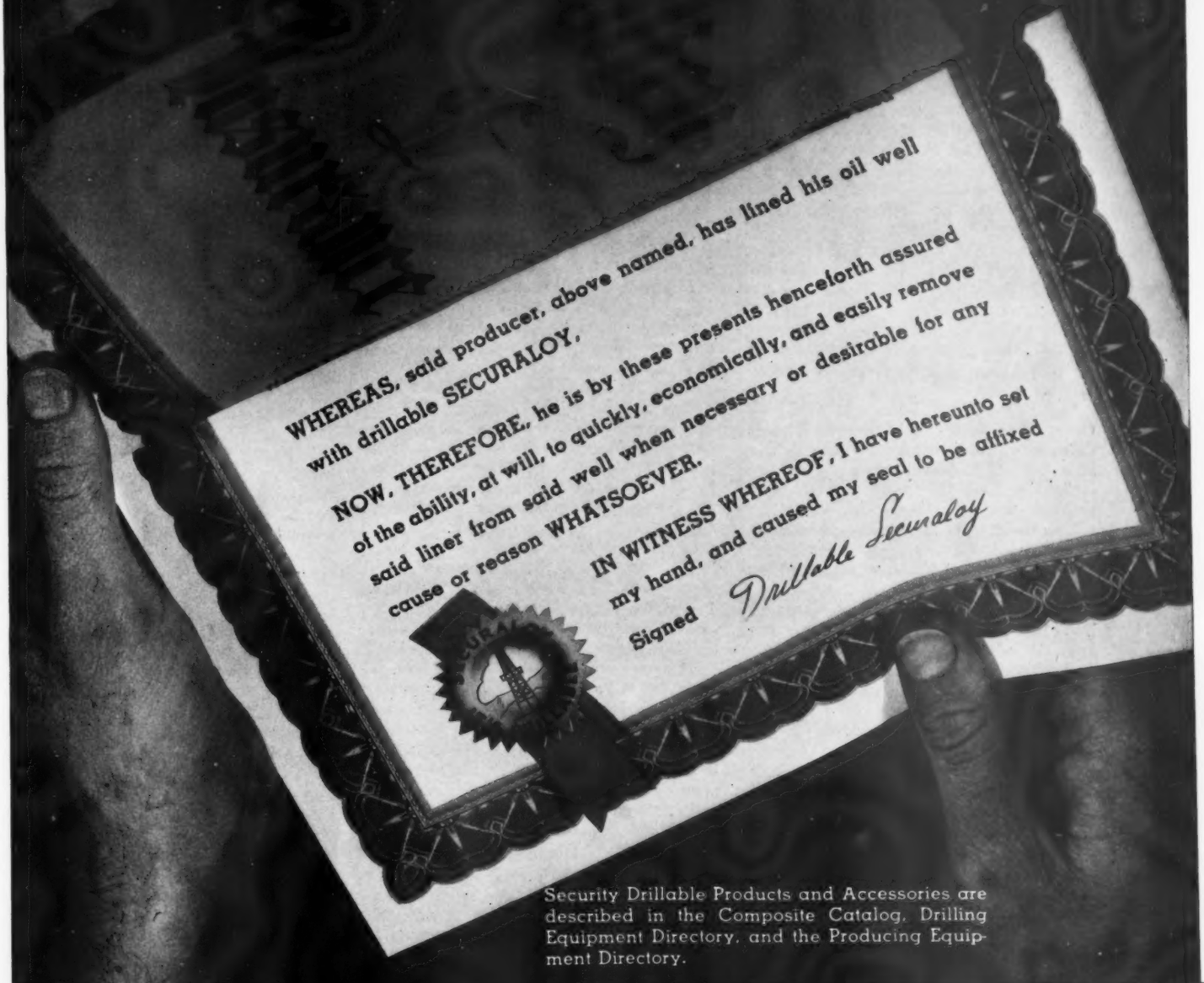
(Continued from page 63)

steady development. The remarkable feature about Bahrein is the existence of four producing horizons between the surface and the 4,700 ft. level which is the deepest yet penetrated. Much of the drilling activity at Bahrein has consisted in carrying the earlier wells which were bottomed at about 2,250 ft. down to the deeper zone. The areal extent of the field has been increased in recent months by the bringing in of several small producers located one to two miles beyond what has been previously considered the productive limits of the field. The extent of this new area and its productive possibilities have not been determined as yet.

Another noteworthy feature of the Bahrein field has been the absence of dry holes. Only two wells were failures out of the 68 completed up to the beginning of the current year and

(Continued on page 94)

Securaloy IS OIL WELL INSURANCE!


WHEREAS, said producer, above named, has lined his oil well with drillable SECURALOY,
NOW, THEREFORE, he is by these presents henceforth assured of the ability, at will, to quickly, economically, and easily remove said liner from said well when necessary or desirable for any cause or reason WHATSOEVER.
IN WITNESS WHEREOF, I have hereunto set my hand, and caused my seal to be affixed
Signed Drillable Securaloy

Security Drillable Products and Accessories are described in the Composite Catalog, Drilling Equipment Directory, and the Producing Equipment Directory.

SECURITY ENGINEERING CO., INC.

WHITTIER, CALIFORNIA • PHONE 42004

MID-CONTINENT: 5525 CLINTON DR., HOUSTON, TEX., PHONE CAPITOL 9535 • NEW IBERIA, LA., (Box 121) PHONE 1370

CENTRALIA, ILLINOIS, P.O. BOX 283

EXPORT: SECURITY ENGINEERING CO., INC., 420 LEXINGTON AVENUE, NEW YORK CITY

Sievers Reamers ★ Securaloy ★ Security Drillable Products

(Continued from page 92)

these were among the earlier tests. While production from Bahrein's wells is restricted by refining and shipping facilities available it amounted to 7,588,000 bbl. in 1939 and is being maintained at around 20,000 bbl. daily at the present time.

A program of crestal gas injection was begun in 1937 in order to maintain reservoir pressure and to obtain a more uniform encroachment of edge water. Results have been highly successful. This is believed to be the largest limestone field in which gas injection has been attempted.

South of Bahrein where the Qatar peninsula juts into the Persian Gulf Petroleum Development (Qatar) Ltd. is reported to have completed its second well. Other concessions at Oman, along the Trucial Coast and on the western side of Arabia are still in the early stages of exploration. The same is true of Palestine and of the concession reported recently to have been granted by the government of Transjordan.

North of Bahrein on the shore of the Persian Gulf and just south of Iraq is the Sultanate of Kuwait where the Kuwait Oil Company, jointly owned by Gulf Oil Corporation and Anglo Iranian Oil Co., Ltd., is continuing its test drilling inaugurated several years ago. The first well drilled proved to be a dry hole but in 1938 a producer was brought in and it is reported now that five wells have been completed.

Since the output of the Iraq Petroleum Company is limited to the 30,000,000 bbl. which its pipe lines can handle annually and since the field at Kirkuk which supplies this oil is one of stable yield and is very efficiently produced there has been little occasion for the company to do new drilling beyond the amount required to maintain its established production level. This is accomplished by keeping one drilling rig in operation.

Just prior to the outbreak of war last year it was reported that the Iraq Petroleum Company was about to proceed with plans for doubling the capacity of its pipe lines. Subsequent events caused this enterprise to be deferred but if and when it goes forward it undoubtedly will be the occasion for an extension of drilling activities.

Two other companies control the drilling rights to all that portion of Iraq not included in the concession of Iraq Petroleum Company. These are the B. O. D. and Basrah Petroleum Company. For several years BOD has been conducting drilling operations and its program is being carried on at the present time. Production is shut in because of lack of transportation facilities and also because of the character of the crude which is a heavy base that requires treatment before it can be shipped or processed.

Basrah Petroleum Company's concession came into existence November 30, 1938. It covers all the southern part of Iraq and is believed to include some very promising areas. Geological and geophysical surveys have been carried on during the past year and the area will soon be ready for test drilling.

Other parts of Asia Minor in which exploratory drilling has been going on during the past year are Syria and Turkey. In Syria the first test well of Petroleum Concessions (Syria and Lebanon) Ltd. was spudded in on February 4, 1939 and a second test was started later in the year. No recent reports of the results of these operations have been received.

Settled conviction that the geologic structure of eastern Turkey as well as its location midway between the great fields of Russia and Iraq justified belief in the existence of important oil deposits has led Turkish officials to support repeated exploratory efforts despite successive disappointments.

Although operating with limited appropriations and equipment the Turkish Petroleum Institute, acting for the Turkish government, has been carrying on a persistent search for oil during the past two years. One rotary and two cable tool rigs have been employed under the direction of American drillers. These efforts were rewarded in April last when the first producing well was brought in at Besiri, east of Dyarbakir. Details of the discovery well have not been supplied but it is stated that it indicated the existence of a field of substantial extent. Further exploratory drilling is under way.

Although Iran is the oldest producing area in the Near East as well as fourth in rank among the producing countries of the world discoveries of new fields and extensions of old ones have proceeded at a rapid rate during the past few years. In the older fields of Masjid-i-Sulaiman and Haft Kel drilling during the past two years has been directed largely to the deepening of existing wells since test borings proved the existence of productive conditions in the Eocene underlying the Asumri limestone which has been the main producing horizon.

Of the new areas developed by Anglo Iranian Oil Co. Ltd. the most important is that of Gach Saran discovered two years ago. Test drillings to delimit the extent of the field have been going forward during the past year. So far as determined the main structure extends twenty miles along the strike and is about five miles across at its greatest width. These dimensions suggest possibilities of large production.

Other new structures on which drilling tests have been going on lie at points 75 miles northwest of Haft Kel, at 50 miles southeast and at 70 miles northwest of Gach Suram. No reports as to progress in these areas have been issued by the company since the commencement of the war.

India, including Beluchistan and the Sind, has been the scene of extensive geophysical surveys during the past year. Exploratory work being conducted by Burmah Oil Company Ltd. has been carried forward with particular attention to extensive core drilling. The information being obtained in this way is being correlated over very wide areas with data obtained from the various geophysical surveys and a broad picture is being built up which, it is hoped, will determine the directions in which still more detailed work should be undertaken. Elsewhere surveys are being conducted by Indian Oil Concessions Ltd. a company in which Standard Oil Company of California and The Texas Corporation are interested together with British capitalists.

With the future clouded by the uncertainties arising from the situation in Europe and the Pacific, very little specific information on exploratory activities in the Far East is available. In general it may be said that geophysical, geological and deep test drilling are proceeding according to the programs outlined previously.

From the exploratory point of view New Guinea leads the East Indies in interest. It will be remembered that Nederlandsche Nieuw - Guinee Petroleum Maatschappij (NNGPM), owned 40 percent by Royal Dutch Shell, 40 percent by Standard Vacuum and 20 percent by California Standard, completed the initial stage in its exploration of Netherlands New Guinea (western part) in 1939. That is to say, aerial reconnaisance had been completed and about 90 shallow, geological bore holes had been drilled up to the end of last year. Most of these shallow tests centered in the South Vogelkop region on the peninsula at the extreme western end of the island. Wasian No. 1 and Sele No. 38, two deep tests in this region have since been completed and other deep tests have since been spudded. It may be assumed that the rigs are still operating in the Vogelkop region and probably no deep tests have been spudded in the vast central section of Netherlands New Guinea as yet. NNGPM has established a well equipped camp at Babo on the south shore of MacCluer Gulf where a staff of about 150 Europeans and 800 natives are housed.

In Papua, the southeastern quarter of the island, Standard-Vacuum's Islands Exploration Co. has one heavy rotary in operation and is continuing extensive geological and geophysical survey work. A third company operating in New Guinea is also working in Papua but further to the east than Islands Exploration. This is Papuan Apinaipi Petroleum Company, Ltd. This company had drilled several shallow bore holes for geological information and it is understood that recently one or more deep tests have been drilled.

Extensive exploration is also being carried out in west central Sumatra where Nederlandsche Pacific Petroleum Maatschappij (NPPM) jointly owned by Standard of California and The Texas Company drilled several important tests in 1939 and where drilling is continuing at present although the results are not available for publication.

Other companies interested in the East Indies are Nederlandsche Koloniale Petroleum Maatschappij (Standard - Vacuum) and Bataafsche Petroleum Maatschappij (Royal Dutch Shell). These companies are carrying on exploration work principally in northeast Borneo and in western Java. It is interesting to note that Sarawak, oldest producing field in the East Indies, is undergoing renewed exploration which, with the modern tools available, may result in discovery of deep production. Another significant center of exploration for 1940 is Brunei where important quantities of crude have been produced for a number of years past.

fly over CHEMICO Installations

Coolies, moujiks, peons—as well as American operating crews—are employed in CHEMICO Acid Plants, for CHEMICO installations are located in every corner of the petroleum-refining world.

This world-wide range of CHEMICO installations is significant of the universal confidence in CHEMICO processes and equipment. Successful service thousands of miles away from the source of advice and supplies demands that a plant be perfectly adapted to individual requirements, sturdily built, simple to operate, thoroughly reliable, and economical in upkeep. CHEMICO Acid Plants meet all of these standards. That is why refining executives have learned to regard CHEMICO as headquarters for acid production and recovery.

CHEMICO places at your disposal the services of long-experienced acid technologists and chemical plant engineers with unequaled resources and facilities. Your inquiry is invited, and authoritative recommendations are offered without charge or obligation.

CHEMICO
CHEMICAL CONSTRUCTION CORP.

Sludge Conversion Plants
Contact Acid Plants
Acid Sludge Separators
Pressure Sludge Separators
Pressure Treaters
Drum Type Concentrators
Flash-Film-Type Concentrators

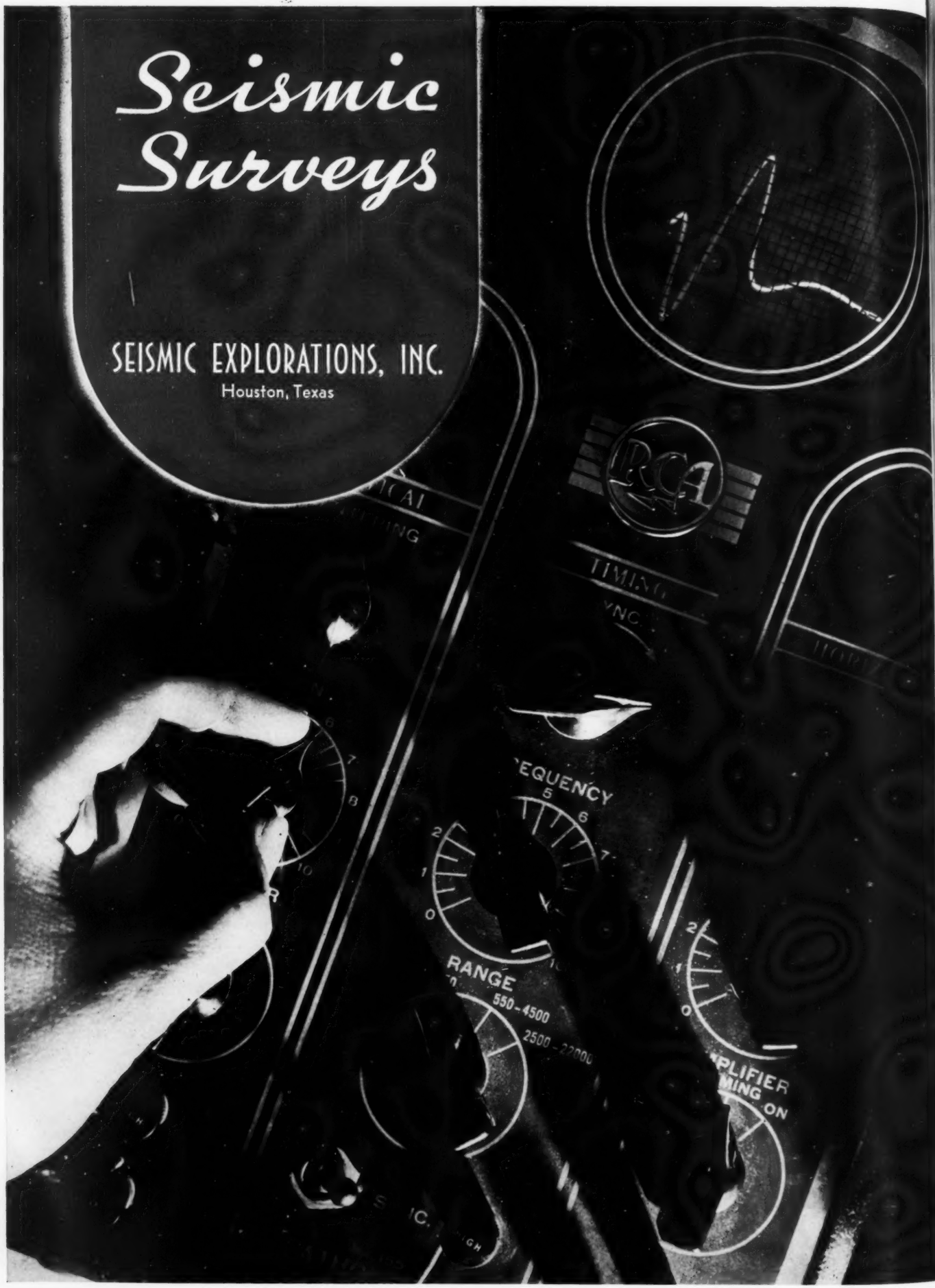
CHEMICAL CONSTRUCTION CORPORATION

Main Offices: 30 Rockefeller Plaza, New York

Cables: Chemiconst, New York

European Representatives: Cyanamid Products, Ltd., Berkhamsted, Herts, England

CHEMICO PLANTS are PROFITABLE INVESTMENTS


Seismic
Surveys
SEISMIC EXPLORATIONS, INC.
Houston, Texas
RCA
RANGE
550-4500
2500-22000

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Petroleum Industry. Edited by Dr. O. W. Willcox

GEOPHYSICS

Some Practical Examples of Micro-Magnetic Prospecting—W. P. Jenny, in OIL & GAS JOURNAL, Vol. 38 (1940), No. 50, pp. 132, 134.

It is said that out of 1,196 wildcat tests drilled during 1939 in Texas, 1,103 or 92.2 percent, were failures. This high percentage of failure in the face of present greatly advanced geological and geophysical experience indicates, first, that oil is increasingly hard to find, and secondly that further improvement of known geophysical methods and the development of new methods are essential.

Some examples are quoted to show that "micro-magnetics", meaning the use of magnetic surveys to predict structures within the sedimentary column (as distinct from the older magnetic method which deals essentially with the basement complex), has by now been developed into a most useful tool of the geologist.

One of these examples relates to the Eola structure in Avoyelles Parish (La.), the top of which coincides exactly with the magnetically predicted apex, and the edges of the structure are fairly outlined. The micromagnetic anomaly here is thought to be due to magnetic beds of Wilcox or lower Eocene age.

Another example is from the northwesterly portion of the Anahuac field. The micromagnetic data indicate positive zones to the west and east and a negative zone along the apex of the structure. A sharp break in the micromagnetic profiles along the east edge of the revealed structure was interpreted as a fault. The micromagnetic data indicated that this fault would not cross the Anahuac-Stowell highway, which prediction was later on proved by the wells.

This example is especially interesting, as it shows that micromagnetic methods alone or combined with gravimetric results give a fair idea of possible structure in a typically Gulf Coastal area.

A third example is the Edwards dome area in Hinds County, Miss., which presents a typical micro-magnetic picture for a piercement-type salt dome, which has been confirmed by the limited amount of drilling that has been done in this area.

A further achievement of micro-magnetics is the identification of a solid plug of unaltered serpentine in Bastrop County, Texas, with a small closure to one side, which was confirmed by the drill.

Limitations of Electrical Logging—Joseph Zaba, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Houston, March 1940; 15 pages.

In the brief period of a few years, since its introduction to the oil industry of this country, the method of electrical logging has met with general acceptance and is now one of the routine operations in oil field exploitation. This acceptance was so rapid and so universal that many of the present users of the method did not have the opportunity to fully learn the technique and the difficulties of interpretation. As a result of this fact there now exists in many instances a tendency to expect to find in an electric log a simple, definite and complete answer to a number of complex and difficult questions. Such a tendency must lead inevitably to costly mistakes and is unfair to the method since mistakes will nearly always be charged, not against the wrong interpretation but against the method itself.

The basic value of electrical logging lies in the fact that certain formational characteristics, of great importance in oil field exploitation, appear in an electric log in form of easily recognizable electrical patterns. The basic limitation of the method, on the other hand, lies in the fact that the electrical log also measures and records a number of factors, which usually have no direct relation to those formational characteristics which are of primary interest when surveying a prospective oil well. Some of these factors are quite obvious and their effect may be easily explained by proper analysis of conditions of the survey. Other factors, however, are not so easily interpreted and they represent the inherent limitations of the method in its present stage of development.

In discussing these disturbing factors the author first considers salinity of the drilling mud. Under ordinary conditions the formations are saltier than the mud, but this condition may be reversed whan a salt mass or brine is penetrated, or when salt is purposely added to the mud in order to overcome certain drilling problems. In such cases the same sand straum may or may not show an electrical anomaly in two adjacent wells, depending on whether one well was drilled with fresh and the other with salt water. Another effect of saline mud is a complete masking of the details of the profile.

The weight of the mud will effect the amplitude of the anomalies of the self-potential curve; increasing the weight will increase the peaks of the curves and in certain cases shift the base line of the shales.

Where the multiple electrode method is used the spacing of the electrodes will affect the pattern of the resistivity curve. The present methods call for standardized spacing, but old logs are clouded by lack of attention to spacing.

Formation pressures that are abnormally high for the depth, by reversing filtration, may obliterate the normal effect of a porous formation on the self potential curve.

Formational characteristics such as hardness will have an effect on the curve pattern and give false indications of a porous, oil bearing sand. The presence of connate water in oil-bearing strata is another confusing circumstance.

Engineers and geologists who have studied large numbers of well logs can find their way through these obscuring factors. Less experienced operators should seek competent advice and consider all pertinent data from related observations.

GEOLOGY

Oil Possibilities in Mississippi —John D. Todd, in OIL WEEKLY, Vol. 97 (1940), No. 6, pp. 17-20, 22, 26.

The author's title for this paper is "Geological study reveals fields better than Tinsley likely for Mississippi." The probability of oil discoveries in the Wilcox, Eutaw, Tuscaloosa and other formations is discussed.

The eventful geological history of Mississippi has resulted in a great variety of structural forms; in fact, nearly every available form of structure is represented in this state. One of the most spectacular forms of structure is the igneous plugs in various counties.

Igneous materials also have been encountered on the Jackson Uplift, and from pronounced magnetic anomalies a number of other igneous plugs are suspected to exist. So far, none of these igneous core structures have proven productive, but most of them have had only one top test and no flank test at all.

The igneous plugs which have drilled are on the more pronounced magnetic anomalies, some with closures of 600 gammas, where it could be expected that the igneous core would be closest to the surface. Those drilled appear to be truly buried mountains, that rise up through 4,000 to 5,000 feet of Upper and Lower Cretaceous sediments. It is suggested that some of the weaker anomalies might represent structures where the igneous intrusion produced only a gentle arching instead of pierced structures; such gentler structures might prove productive of gas if not of oil.

Another form of structure known to exist in the area is the large anticline. Examples of this are the Hatchitigbee Anticline, just across the line in Alabama with the west and extending into Mississippi; and the Alamucha Anticline in Lauderdale county.

One of the type of structures most easily detected by geophysics is the piercement-type salt dome. Two such salt domes have been found; the Midway Dome in Lamar County and the Edwards Dome in Hinds County. Additional salt domes of the piercement type are strongly suspected from geophysical evidenee. The existence of deep-seated salt structures has been proven by the discovery of the Tinsley field.

The possibilities of stratigraphic exploration are yearly coming more into prominence everywhere, but there is no place where the possibilities of stratigraphic trapping are more obvious than in Mississippi.

The Eutaw and Tuscaloosa both pinch out in west central Mississippi, so there is a real possibility of one or more East Texas-type traps in that area. Similarly the entire Upper and Lower Cretaceous pinch out over the igneous ridge in Sharkey, Washington and Humphreys counties; thus affording other possibilities of up-dip pinch-out stratigraphic traps. In the same manner these

ormations, and perhaps others, do not go across the Jackson Uplift, thus affording possibilities of pinch-out fields all the way around the uplift. Several of these cases are so similar to the pinch-out of the Woodbine in East Texas that several wells are already drilling.

Another possibility of stratigraphic trapping afforded over a large part of the state is the angular unconformity between the base of the Cretaceous and the underlying Comanchean and Paleozoic beds. This truncation and overlap must result in many porous limes and sands being sealed by impervious beds above. The possibilities of this type of trap are so widespread and enormous, as to lend unusual possibilities to even the random wildcat, so long as it drills through the Cretaceous.

DRILLING

Rotary Completion of Gas Wells in Texas Panhandle—J. M. Gardner, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Wichita, March, 1940.

Circumstances made it desirable to effect faster completions of gas wells; conventional cable-tool completions and conventional rotary completions, using either mud or oil as circulating media were ruled out as impractical for the purpose contemplated. Finally, it was decided to use gas as a circulating medium with only enough water injected into the gas stream to afford the necessary lubrication and cleaning action for the bit.

Seven wells have been completed with use of the gas-rotary method, and it appears that there may be a saving of ten days by this use of rotary over cable tools. It has been found that from 2,500 MCF to 3,500 MCF throughput at pressures varying from 250 to 350 lbs. per square inch is sufficient to keep the hole clean; the most satisfactory rate of injection of water is one to two bbl. per hour. Bit performance has been surprising; runs have averaged consistently over 100 feet, at rates of penetration of two to 30 feet per hour. Aside from the more rapid completion the principal advantages are elimination of the cable tool personnel problem, simpler organization and smaller investment.

A Comparison Between Electrical Logging and Core Analysis—P. B. Leavenworth, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Houston, March 1940.

Oil operators at times may have difficulty in choosing between two of possibly similar character, both of which have points of merit; two such services are electrical well logging and core analysis, each of which furnishes some data not indicated by the other; proper correlation of these data aids in the solution of certain problems which constantly confront the operators. These problems include correlation, well completion, estimates of oil and gas, and well spacing. A proper understanding of the benefits obtainable respectively from electrical logging and core analysis is necessary in evaluation of these services with respect to their use in solution of the foregoing problems.

In deciding between core analysis and electrical logging the author offers the following suggestions:

Regional Correlation: The electrical log is probably sufficient.

Field Correlation: For the determination of structure the electrical log. For details of the producing section both electrical log and core analysis.

Well Completion: Both are of value as great detail is often necessary to successful completion, particularly in thin sand fields and where gas and water problems are important.

Estimates of Oil and Gas: Both are of value as the same problems exist as in well completions.

Well Spacing: Both are valuable, as core analysis may indicate rate of efficient withdrawals and electrical logs the structure and thickness of pay members.

One well-known difficulty with electrical logging is that it may not clearly differentiate between an oil or gas show, a hard sandstone or limestone, lignitic material, and fresh or sulfur water. Core analysis gives a surer discrimination. Instances of such failures of electrical logs are well known, as for example the Anahuac field, where the oil section contains a large percent of connate water and thus shows no increase in electrical resistivity. Important sections in wildcats or fields should therefore be carefully cored.

Cable Tool Drilling—Kurt Springling and Eugene A. Stephenson, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Wichita, March, 1940.

This is the report of an investigation of the relation between the natural frequencies of cable tool systems and the optimum number of operating strokes per minute.

It has long been recognized, among experienced drillers, that in order to maintain maximum drilling efficiency some alterations in the number of drilling strokes per minute are necessary as the depth of the drilling increases. After spudding has been completed, and beam drilling commenced, the driller begins to search or "feel" for the engine speed at which the strokes per minute will give the best action to the tools. His only immediate source of information concerning the action of the tools, in response to variations in engine speeds, is found in the "feel" of the drilling cable just below the temper screw and clamp. He therefore endeavors to modify the speed of the engine to accord with that obscure "feel" of the line, which his experience has taught him produces most efficient results. However, a variety of obstacles tend to hamper and confuse him in his choice of the speed. For example, as the depth increases, the vibrations transmitted by the cable tend to damp out, and become more difficult to "feel", while the limitations of the engine itself tend to induce him to employ some other speed than that which his experience indicates. Without any mental segregation of these complexities, the driller knows full well that he must operate with a sufficient number of strokes per minute to make a profitable amount of hole per hour. Such footage is fundamentally a function of the number of impacts on the formation.

It is now known that the force or impact of the bit on the bottom of the hole depends on the coincidence or lack of coincidence of two "frequencies". One of these frequencies is the period of the working stroke of the engine, and the other is the frequence of the period of vibration of the drilling cable. If these coincide, or are in harmony, the force of the blow will be a maximum; when the two frequencies are not in harmony the force will be weaker.

The natural frequency varies with depth. Thus, the drilling frequency from the spudded depth to about 600 feet under certain conditions would be an harmonic ¼ of the natural frequency. At this point it would be necessary to shift from the harmonic ¼ to the harmonic ½ of the natural frequency. It is these harmonic points that the practiced driller seeks to find by the "feel" of the line.

To assist in putting the matter on a scientific rather than an empirical basis the authors present a monogram and charts which show how to determine the natural frequencies of cable tools and how to work out a drilling program by varying the number of strokes per minute to maintain drilling frequencies corresponding to harmonics of the natural frequency at various depths.

Geochemical Well Logging—E. E. Rosaire, in OIL & GAS JOURNAL, Vol. 38 (1940), No. 50, pp. 114, 116, 119.

Geochemical logging of an oil well, as the author presents it, is a matter of taking drilling samples as the bit goes down and examining the cuttings for the presence of hydrocarbons. The principle is that where an oil-bearing sediment has been buried for perhaps millions of years traces of the oil will diffuse through the overlying rocks, and this is true whether the pay is 13,000 feet deep, as at the Wasco field in California, or only 1,500 feet deep, as at the Ezzel oil field in South Texas. The diffusion extends not only vertically but also laterally. The main point appears to be that so long as the drill cuttings show traces of hydrocarbons sufficient to interest a qualified geochemical well logger, the driller may conclude that the bottom of his hole is still above the pay. Reference is made to a case where production was established by trusting geochemical evidence in a zone where the electrical log indicated no sand, let alone "saturation".

While geochemical logging in this sense is still very recent the author feels warranted in making for it the following claims:

"Dry" holes can be graded qualitatively as to their closeness to a petroleum deposit.

Zones can be recognized which are practically barren of petroleum, and so need not be cored.

Zones can be recognized which contain significant amounts of petroleum hydrocarbons, and which, therefore, should be carefully cored.

The vertical extent of such potentially significant zones can be recognized. That is, the geochemical log shows when the drill has passed through such zones of higher concentrations.

The geochemical well log distinguishes between the high pressure due to gas and the high pressure due to salt water, a problem which recently has become of interest in the Gulf Coast.

"Dry-hole prospecting" is made possible by grading the geochemical logs of dry holes on a prospect as to their qualitative proximity to a petroleum deposit if one is present nearby.

Significant structural variations cannot be expected at shallow depths over stratigraphic traps and deep-seated, low-relief structures. In these cases, the lateral variations displayed by geochemical well logs makes "slim hole" testing of considerable utility in locating the petroleum deposit itself as well as its areal extent.

In effect, the geochemical well log extends the vertical penetration of the bit downward some 500 to 1,000 ft., and laterally as much as ¼ to ½ mile, permitting the qualitative estimation of the extense of a petroleum deposit in those adjacent sediments not penetrated by the bit.

The geochemical well log contributes independent quantitative evidence as to the presence or absence of "shows," and, if such are present, the log indicates the relative percentage of "gas" and "distillate" hydrocarbons present over the full range of section in which such appreciable concentrations occur.

Oil Well Cementing—P. H. Jones and Denis Berdine, before AMERICAN PETROLEUM INSTITUTE, Pacific Coast Division, Los Angeles, March, 1940.

An experimental study was made of factors

The GREATER THE PRESSURE THE TIGHTER THE SEAL!

Available in both famous brands:
U. S. MATCHLESS
U. S. PEERLESS
Rotary Hose

UNITED STATES RUBBER COMPANY
US
TRADE MARK

United States
Rubber Export Co., Ltd.
1230 SIXTH AVENUE, NEW YORK, N. Y.

New LEAKPROOF COUPLING FOR U. S. ROTARY HOSE

- ★ Revolutionary coupling principle.
- ★ Streamlined and permanently sealed against leakage.
- ★ Hose and coupling perfectly balanced under full pressure.
- ★ Increased fluid area assures full flow.
- ★ New method of anchoring coupling minimizes stress on hose.
- ★ Built-In as integral part of hose.
- ★ No flanges, clamps, nozzles, bolts, nuts, hydraulic nipples, or other gadgets.
- ★ Easy to connect and maintain.
- ★ Eliminates losses and shutdowns caused by leaks.
- ★ Coupling made of toughest alloy steel. Complete fittings weigh less.
- ★ Performance proven *in advance*, in laboratory, and in field.
- ★ Tested at Factory, at pressures in excess of those encountered in actual service.

★ ★ ★

- ★ Hose has great strength . . . more than enough for all drilling pressures.
- ★ Hose remains flexible under all drilling pressures.
- ★ Hose readily assumes natural position on rig.
- ★ Reinforced ends.

Made, tested, and backed by United States Rubber Company, famous for Rotary Hose, and other oil field products.

SERVICE BEYOND PRICE AND SPECIFICATIONS

influencing the set between cement and formation, with special reference to the interference of mud cake that persists on the wall of the hole, which is one of the reasons of channeling and failure to obtain a satisfactory cement job. On this point the following conclusions are stated:

Channeling and chimney formation of cement in the annulus is unlikely in the immediate region of the shoe but may occur near the top of the cement column. Wherever cement slurry is applied opposite formations having appreciable permeability, a residual mud cake will remain between the set cement and the formation unless specific means are employed to effect its removal. The presence of collars, movement of the casing, or circulation of water may reduce the thickness of the mud cake slightly, but will not remove it completely. Where the casing rests against the walls of the hole, residual cakes will be thicker than normal. There is a tendency for the cement slurry to be excluded from such regions of proximity, thus leaving longitudinal stringers of mud cake with no cement between the casing and the formation. Three methods were found to be effective in removing mud cakes: (1) Hydraulic action by direct impingement of fluid jets against the walls of the hole; (2) mechanical scraping by using mechanical devices on the casing, and alternately raising and lowering the casing. This is effective only over areas where scrapers or scratchers make a bearing on the wall of the hole; (3) acid treatment gave best results under atmospheric pressure conditions. Laboratory tests at high pressure indicate but do not prove effective mud-cake removal.

OPERATION

Gun Perforation and Acidization of Limestone in the Permian Basin—J. A. Jones, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Houston, March, 1940; 9 pages.

A new method of well completion is attracting a great deal of favorable attention in the fields of the Permian Basin. It consists of selectively gun perforating the saturated lime pays below casing and then treating with several stages of acid. Increased penetration of acid through perforations is thus obtained wherever desired in the pay section without impairing the well for further operations or necessitating the lengthy cleanouts associated with nitro completions.

In most wells there is a very thick pay section, and frequently there are great changes in the saturation, porosity, permeability, and density between the top and the bottom of each zone so that often any type of completion that affects the pay section as a whole will not give the best results.

This is one of the main reasons why the selective gun perforation of the saturated zones according to the formation variations in each well has been giving such good results.

Experiments made in quarries where the Hunton and Arbuckle formations are exposed, to determine the amount of penetration that is obtained, show that gun perforation of open lines results in penetration of ten to fourteen inches. It was found also that the penetration was increased by wetting the limestone; when the formation was saturated to the depth of about two inches, the penetration of the bullet was increased by about four percent. It was observed that the hole made in the formation is cone-shaped with the mouth many times larger than the diameter of the bullet, thereby exposing a large surface to the acid treatment. The number of shots per foot will greatly affect the amount of surface in the formation that is exposed to the action of the acid.

The usual procedure is to perforate and then acidize. Old wells about to be placed on the pump may be given the same treatment.

Electrification of Pumping Equipment in Illinois—R. E. Hammond, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Columbus, March, 1940.

Electric power has been used for oil well pumping throughout the petroleum industry for the past 10 to 15 years, but the more recent development of oil fields in the Illinois Basin has brought a stronger tendency toward the use of electric pumping equipment than any of the older producing territories. Illinois Basin operators who have chosen this producing method have been influenced largely by the depth and producing characteristics of these wells. The relatively shallow depths and low potentials permit the use of small electric motors and distribution equipment, thus reducing the initial investment from that required for deeper wells, while the anticipated long producing life of certain pools allows the maximum benefit of the low operating expenses usually obtained with the use of electrical equipment. The choice of electric pumping might also be influenced by the availability of small sized unit pumpers, by the topography of the field, by the well spacing pattern, or by any number of other considerations.

In selecting equipment it is recommended that special consideration be given to the advantages of "high slip" induction motors, time switch control for automatic operation of the wells, location of field sub-stations to permit "looping" and underbuilding of secondary lines, setting the pumping unit on side of well toward power line, avoidance of overbuilding generator plants by purchasing power for temporary peak loads, stabilization of power load and arrangements for more power during cold winter months.

Typical wells in Illinois are equipped with electric motors ranging from 3 h.p. to 7½ h.p. rating. Actual demands range from about 0.7 k.w. on a 1,500 foot flush well which tends to agitate and flow part of its production to about 5.0 k.w. on a fully loaded 7½ h.p. motor. Electric energy consumption in a flush pool will range from 0.2 to 0.4 hilowatt-hour per barrel pumped, depending upon the fluid level and state of agitation. As the wells decline, this consumption will gradually increase to an expected ultimate of 0.8 to 1.0 kilowatt-hour per barrel of fluid pumped. In order that these figures can be converted into a money cost per barrel pumped, it is necessary to know the cost of a kilowatt-hour delivered to the well. A reasonable estimate of the average expense of maintaining and depreciating an electric power distribution system might vary from 5 to 8 mills per kilowatt-hour, which cost must be added to the price of energy at the source. In the special case of an oil producer who operates his own generating plant and enjoys certain economic advantages, such as free fuel gas and low operating labor expense, electric power frequently is produced for from 5 to 8 mills per kilowatt-hour at the generator, making the total cost range from 1.0c. to 1.6c. per kilowatt-hour at the well.

Submergible Electrical Centrifugal Pumping Units and Their Application—P. E. Loye, before AMERICAN PETROLEUM INSTITUTE, Division of Production, Wichita, March, 1940; 8 pages.

The author describes pumping equipment which utilizes the principal of placing the pump at the bottom of the well and operating it by electrical power transmitted from the surface through a cable.

This method of pumping was first used some ten years ago, during which time more than 70 wells have used this type of equipment; installations are now in operation in New York, Michigan, Illinois, California and each of the Mid-Continent oil producing states; electrical, submergible, centrifugal pumping units can now be purchased with motors from 3½ h.p. to 135 h.p. units within this range are in use pumping volumes up to 13,000 bbl. daily. They have been operated at depths from 500 to 8,500 feet to produce from 5 to 14,000 bbl. a day. It is estimated that these submerged pumps have to date lifted more than 300 million bbl. of fluid.

One characteristic of these units is that they can be installed and operated in a crooked hole, with no wear on tubing or casing. Since no rods are employed small tubing may be used, selected from a condsideration of efficient flow only. For production rates up to 20 bbl. per hour 1¼ inch tubing is satisfactory.

Since the submergible motor and pump are cooled by the fluid in the well, heating of the oil occurs, reducing paraffine deposition and, if some water is produced, reducing emulsion. If this heat does not completely eliminate paraffine deposition an automatic paraffine scraping go-devil may be placed in the tubing string. When the pumping unit is stopped the scraper falls to the bottom and when the unit is started, the go-devil is pumped to the surface scraping out paraffine as it goes.

A unit running at full load will assume a temperature of about 60° F. above the temperature of the well fluid so if the unit is installed opposite the producing formation in wells giving trouble from paraffine or asphalt deposition in the hole, this heat tends to keep the pores open on the face of the formation.

Another unique feature of this equipment is that no foundation or setting expense is required, hence all of the investment items can be salvaged at the end of the operation. The amount of power which can be delivered to the pump is only slightly affected by depth. Corrosion troubles are readily eliminated with this type equipment, since the well fluid does not come in contact with the working parts of the motor and the working parts of the pump are built of corrosion-resisting materials.

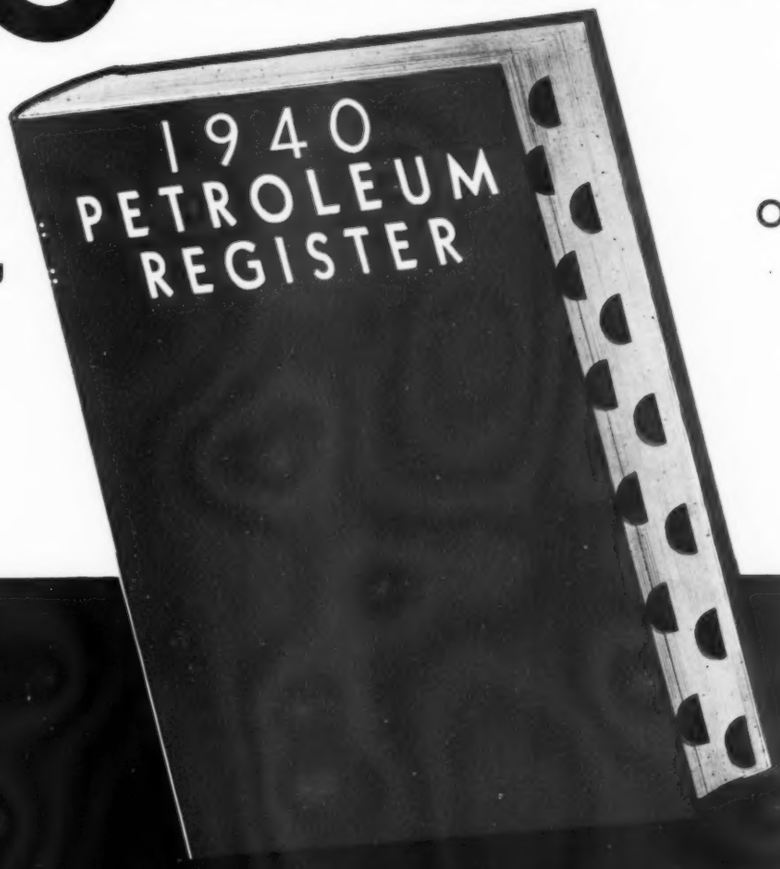
In discussing the application and operating results obtained in the regular production of oil wells it is convenient to classify the types of wells into four general groups: First, small allowable wells in water-drive fields; Second, small-capacity wells in fields with low fluid levels; Third, wells from which it is necessary to produce large volumes of water to obtain the allowable, and; Fourth, deep wells where large horsepower units are required to make the operation of the well profitable. In the first group the average pumping cost per bbl. of fluid lifted through 1,000 feet is 11.1 mills; in the second group 16.0 mills, in the third 5 mills and in the fourth 10.3 mills.

Optimum Spacing of Dolomite Acreage in the Texas Panhandle—Park J. Jones before AMERICAN PETROLEUM INSTITUTE, Forth Worth meeting, May, 1940.

The author presents data showing that ultimate recoveries within 10- to 20-acre limits on the Panhandle dolomite are independent of spacing. Based on the following representative physical, data; an allowable of 20 bbl. per day per well irrespective of spacing; 365 operating days per year; an economic limit of 3 bbl. per day; an investment of $22,500 per well; an operating cost of $1,800 per well per year, including taxes; a one-

1940 EDITION *Now Ready*

The Only
OIL DIRECTORY
Completely Covering
The Industry



Only One
OIL DIRECTORY
To Buy

SIZE
11¾" x 8¾" x 2½"

AN ALL PURPOSE DIRECTORY—MORE THAN 1200 PAGES

1940 EDITION LISTS:

1,000 Oil Producers in the United States.

200 United States Refining Companies.

Over 1,200 refineries; processes used, capacities, superintendents' names, etc., in 52 foreign countries and 32 states.

The most complete data relating to pipe line operators ever published including superintendents' names and more than 500 pipe line companies.

1,800 Drilling Contractors in 20 states.

Licensed wholesale distributors in every state of the Union.

Oil Trade Associations, Government Bureaus and Commissions.

Thousands of men engaged in the production of crude, listed by companies or individually with titles and individual addresses.

Licensors and owners of cracking and other refining processes; natural gasoline plants with locations; compounders and grease manufacturers; register of 1,500 tank ships; bunkering stations the world over; operators, refiners and marketers in 150 foreign countries; 9,000 trade names; 5,000 professional men, etc., etc.

1940 Petroleum Register (21st Edition) contains over 25 per cent more names and addresses of oil companies and oil men than any oil directory ever published. The vast number of changes and additions make imperative the use of this new edition for reference by executives, purchasing and all other departments or as a general mailing list. All valuable features of former editions have been retained, including the Buyers' Guide Catalog.

Two large oil directories (The Petroleum Register and World Petroleum Directory) combined in a single edition at no increase in the former cost for one of them.

WORLD PETROLEUM
95 River St., Hoboken, N. J.

....., 1940

Ship one copy of **PETROLEUM REGISTER** to the address below, for which the undersigned agrees to pay $10 and transportation charges as indicated at left. (Foreign $12.00, including transportation charges.)

Signed .....

By .....

.....

.....

POWER . . . *assumed* . . . real

Canute, King of England, Norway and Denmark wearied of the flattery of his courtiers, who held him all-powerful. To teach them otherwise, he commanded the tide to stand still . . . and they quickly learned that he had no power over natural forces. The water . . . under the pull of the moon's gravitation . . . would not halt . . . but moved inexorably toward the disillusioned group.

Oversized pigment particles in enamels, water or wax in petroleum stocks, and other undesirable matter . . . subjected to the pull of Centrifugal Force, when passing thru a Sharples Centrifugal . . . all must feel as bewildered and helpless as did this Royal Group.

A power of over 13,000 times gravity is not theoretical . . . it is real . . . it acts with authority.

SHARPLES

THE SHARPLES CORPORATION

★ *CENTRIFUGAL AND PROCESS ENGINEERS* ★

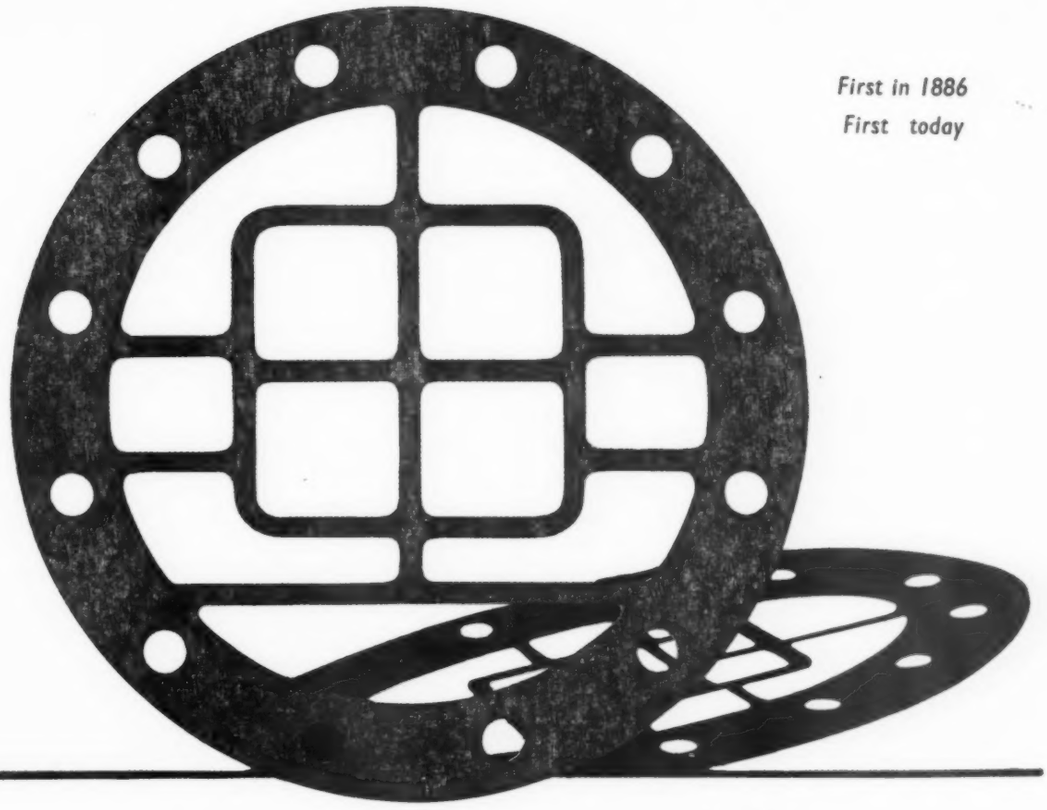
2323 WESTMORELAND STREET · PHILADELPHIA · PA.

London *Paris* *Tokio*

New York *Boston* *Pittsburgh* *Cleveland* *Detroit* *Chicago* *Dallas*

Seattle *San Francisco* *Los Angeles*

REPRESENTATIVES THROUGHOUT THE WORLD



First in 1886
First today

"Klingerit"

"KLINGERIT," the original Compressed Asbestos Jointing (sheet packing), has served the Petroleum Industry since its earliest years. The most convenient and safest jointing material available—for refinery plant, stills, pipe lines—wherever lasting joints and resistance to heat, pressure, oils, chemicals and steam are required.

"Klinger-Oilit"

"KLINGER-OILIT" is a Jointing Material specially designed for petroleum work, particularly when it is not required to use such a high grade material as "Klingerit." It is absolutely resistant to oils of all types and can be used for medium pressure steam lines, natural gas and water lines, etc. Being somewhat softer than "Klingerit" it takes the place of perishable jointings such as rubber insertion and cork and is a valuable general purpose jointing.

GASKETS

RICHARD KLINGER LTD. KLINGERIT WORKS, SIDCUP, KENT, ENGLAND

eighth royalty; and interest at 6 percent, it appears that, on the average, optimum spacing of the dolomite acreage in the Texas Panhandle is 18 acres per well at the present income of $0.98 per barrel of oil produced. A more general statement reads thus: The optimum spacing on the dolomite acreage is 1 well per 136,000 bbl. of recoverable oil.

REFINING

Testing Non-Ferrous Alloys for Condenser Tube Service under Conditions Simulating Actual Industrial Service—R. W. Moore and S. Kleinheksel, before AMERICAN PETROLEUM INSTITUTE, Forth Worth Meeting, May, 1940.

A favorite method of investigating the suitability of a metal for use in condensers is to place strips of the metal in the fluid which produces corrosion, and after a longer or shorter time weighing the strips to see how much metal has been eaten away.

It is now realized that this method does not give sufficient information on which to base a judgment of the suitability of the metal. For instance, damage to copper alloys by dezincification, pitting or intercrystalline corrosion may not show up as an appreciable loss of weight. One of the important requisites of a condenser tube is that it should retain a large measure of its tensile strength, which may be nearly lost without much change of weight. For this reason prominence is given to the method in which strips of the metal, cut in the usual form for mechanical testing, are inserted in an experimental condenser from which they are later removed and their strength determined.

The results of the investigation, combined with the results of actual refinery operations, indicate that Admirality tubing, which is used in most non-ferrous condenser installations, is "quite satisfactory" even under severe corrosive conditions.

However, it is pointed out that besides studying the anti-corrosive qualities of metals, there is undoubtedly much profit to be had by studying the properties of the corrosive refinery fluids, and economic means of correcting them. Such means will include deoxygenizing the cooling water, the use of chromates, cathodic protection, etc.

Corrosion of Copper and Copper-base Tubing in Oil Refinery Heat-Transfer Equipment—R. A. Wilkins, E. S. Bunn and W. Lines, before AMERICAN PETROLEUM INST.TUTE, Fort Worth Meeting, May, 1940.

In bringing up again the subject of corrosion of oil-refinery equipment the authors admit that many of the factors which contribute to corrosion of tubing in heat-transfer equipment are variable or quantitatively indeterminable. Hence, corrosion rates in service cannot be ascertained by means of laboratory tests. Cumulative operating experience, properly interpreted, is the most reliable (albeit costly and imperfect) guide to the selection of an alloy. A short cut to knowledge of the effect of service conditions on the tubing sometimes is attempted by placing test samples of alloys in the heat transferrer. It should be realized that the method is an approximation. Conditions at the surfaces of the test specimens do not duplicate conditions at the surface of the tube except fortuitously.

Optimum corrosion resistance is manifestly an inadequate criterion for the selection of a suitable material for heat-transfer tubing. Sound engineering practice requires a balancing of original alloy cost, and the costs of installation, maintenance and shutdowns, so that the sum shall be a minimum. In certain cases obsolescence of equipment may be a paramount consideration.

As regards ferrous materials, the bulk of such heat transfer tubing used in the refinery fall under three general classifications: 1, straight-carbon; 2, 5-per-cent-chromium–½-per-cent molybdenum, and variants; and, 3, 18 percent chromium–8 percent nickel, and modifications. The generally poor corrosion resistance of the straight-carbon steels circumscribes their applicability. The low-chromium-alloy steels (type "2") have some resistance to hydrogen sulfide, but are otherwise mediocre. The 18-8 type of stainless steel has excellent resistance to hydrogen sulfide, but is handicapped by high cost and negligible resistance to hydrochloric acid. Also, rapid failure has occurred on the water side of the 18-8 condenser tubes.

As regards copper, in which the authors are mostly interested, it is maintained that this metal and its alloys have sufficient mechanical strength for most heat transfer operations, and in the present improved forms of Admirality metal and Muntz metal are capable of giving a good account of themselves both technologically and economically, especially in view of recent progress in the neutralization of corrosive crude oils.

Some Variables in Filter Clays—L. M. Henderson, C. M. Ridgway and W. B. Ross,. before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May 1940.

The influence of water, carbon, and porosity on the filter efficiencies of Florida clays used on Pennsylvania cylinder stocks and bright stocks was investigated. In addition, a limited number of tests was made on bauxite clays.

It has been observed that the water is present in the clay in two states of affinity. Part of the water may be held loosely and removed readily at temperatures of about 450 deg. F., whereas another part of the water is held more tenaciously and is removed completely only on heating to almost 1,800 deg. F. The former type of water has been termed "adsorbed" water; the latter, "bound" water. The filter efficiency of a Florida clay decreases appreciably if the bound-water content is less than 2 percent. The adsorbed water content appreciably affects the efficiency of the Florida clay if it is above 1 percent. Inasmuch as freshly roasted Florida earth picks up moisture from the air rapidly at atmospheric temperatures, it is shown that the handling and storage of the clays, subsequent to their burning and prior to filtration, is an important factor in maintaining the filter efficiency of the clay.

The presence of carbon affects adversely the yield and cast of Pennsylvania cylinder stocks of 8 NPA color. The influence of carbon on a 5NPA bright stock is not as great. The filter efficiency of Florida earth increases with porosity, inasmuch as the total surface area per gram of clay is a function of the porosity of the clay.

Application of Superheated Steam to Combination Unit Prime Movers—A. E. Harnsberger, before AMERICAN PETROLEUM INSTITUTE, Fort Worth meeting, May, 1940.

This paper summarizes an investigation made by a refiner on the best method to meet the power requirements of a 25,000-bbl. crude-charging-capacity combination unit. It was necessary to adapt the installation to meet the limited steam-production facilities in an existing plant.

The investigation revealed the practicability of generating steam from waste heat. By superheating the steam to the largest power-consuming units, and by condensing the steam from these units under vacuum, it was possible to reduce the steam requirements and make a boiler-house extension unnecessary.

The steam generator employed consists of a horizontal drum in which is held a constant water level by the feed-water pump. Ranged alongside in vertical position are six tubular exchangers, the shell sides of which are connected to the drum. Water is fed from the drum into the lower section of the shells, the circulation being thermosyphon. Recycle oil, topped crude, and residuum are pumped through the exchangers. After 18 months of operation this waste-heat generator has proved to be entirely satisfactory, operating with a minimum of trouble and expense.

The superheating of that portion of the steam to be consumed by the condensing turbines is accomplished in a separately fired unit.

Significance of the Doctor Test for Gasoline.—John Happel and S. P. Cauley, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

A critical review is presented covering the significance, to both consumer and manufacturer of the doctor test as a gasoline specification. From the viewpoint of the former, the question of odor frequently is associated with this test. Data presented indicate that the test does not give a true indication of acceptable gasoline odor; and that the practical limit of mercaptan concentration in a gasoline, without causing objectionable odor, is usually much greater than that demanded by the sensitivity of the test.

It is concluded that, for the best interests of all concerned, the mercaptan concentration in a finished gasoline should be a matter of economics, and should not be fixed by an arbitrary test giving no real indication of gasoline quality. Its limited general use by agencies other than the refiners themselves, together with its lack of significance, should aid in the elimination of the doctor test as a gasoline specification. It does not appear in U. S. government specifications and is legally required by only one state. There is no ASTM standardized test for it.

Cathodic Protection of Condensers and Coolers Utilizing Brackish Bay Water—W. A. S. Wright and J. H. Brooks, before AMERICAN PETROLEUM INSTITUTE, Fort Worth meeting, May, 1940.

Rapid failure had occured in red-brass tubes installed in a surface condenser operating on brackish bay water. These failures were attributed to deposit attack caused by the entrance of foreign material into the tubes.

The red-brass tubes were replaced with admiralty metal, and a system of cathodic protection installed based on an impressed current of 2.5 amperes per 1,000 sq. ft. of tube surface. Some minor pitting of the tube ends has occurred since cathodic protection was applied; but, after 14 months of service, no failures have occurred, and no serious depreciation has been reported.

Cathodic protection has been applied also to additional refinery cooling equipment, and during 16 months of service no failures of tubes have occurred.

Results of Corrosion Tests in Oil Refineries—N. W. Mitchell, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

This series of corrosion experiments was carried out by determining the decrease of the tensile strengths of exposed test pieces. They show the marked superiority of alloys of the admiralty range of copper content over red brass. In a number of cases antimonial admiralty and

STEEL TUBES WITH VICTAULIC JOINTS FOR OIL.

The photograph shows part of an installation of 10" 'S & L' oil pipe lines with Victaulic joints.

Victaulic joints provide valuable flexibility in allowing for expansion and contraction and rise and fall of pipes due to the slight movement of the storage tanks.

Stewarts and Lloyds also specialise in all oil-field tubular goods.

STEWARTS AND LLOYDS, LTD.

GLASGOW · BIRMINGHAM · LONDON

BUILT FOR "FOREIGN" SERVICE

CHIKSAN *All-Steel* ROTARY HOSE

Tested and proved by years of hard service in foreign fields. Compact for easy handling. Not affected by climatic conditions or age. All-Steel Construction, but the lightest weight High Pressure Rotary Hose built. Compare hose weights for your own satisfaction.

4", 5" FOR DRILLING,
3" FOR STANDBY AND PRESSURE SERVICE.
45'-50'-55'-60' LENGTHS

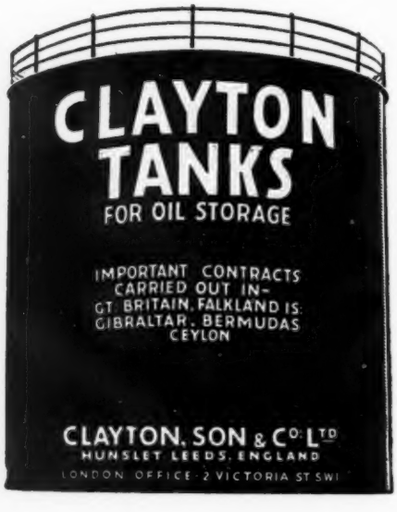
BUY THE HOSE THAT FITS YOUR PUMPS

R. J. Eiche, Export Representative
50 Church St., New York City

CHIKSAN BALL BEARING SWING JOINTS

CHIKSAN TOOL COMPANY
BREA, CALIFORNIA

BALL BEARING SWING JOINTS for ALL PURPOSES
ALL-STEEL ROTARY HOSE
CIRCULATING HEADS • MUD GUNS
THREE-WAY DISC BIT
STANDARD AND HEAVY DUTY REAMERS



admiralty behave approximately the same, but there are other cases in which the antimonial admiralty appears to be distinctly better in resisting sulphur attack on the oil side of condensers. An explanation for this occurrence is that in many cases, even in vapor streams, corrosion of admiralty occurs by dezincification due to the presence of steam or water vapor in the fluid. Simultaneously with the formation of a copper layer by dezincification, sulfur attack removes this copper layer as it forms. Antimonial admiralty—being, as far as we have been able to determine, immune to dezincification—does not suffer such attack. This accounts for the differences in the cases noted.

In other cases, in which water corrosion was the principal cause of destruction antimonial admiralty has again shown its superiority over admiralty.

ECONOMICS

World Motor Vehicle Registrations in 1939—Oskar Tokayer, in PETROLEUM PRESS SERVICE, Vol. VII (1940), No. 12, pp. 138-139.

Estimation of the number of motor units in use throughout the world has been rendered more difficult than usual by the outbreak of war and the cessation, in some instances of the publication of official statistics. Although the figures are admittedly incomplete for all territories it has been estimated that the number of motor units in the world (excluding motor-cycles) advanced from 42,780,500 to 44,542,100; this increase of about 4 percent corresponds with the estimate made by the American Automobile Manufacturers' Association. In the United States the increase amounted to 3.4 percent (30,180,224 as against 29,158,615 units); the rest of the American contingent, with an aggregate of 2,309,100 units, compared with 2,214,626 in 1938, shows a 4.3 percent advance. The number of vehicles in use in Europe is put at 9,463,293 (compared with 9,065,475)—an increase of 4.4 percent; in Australasia at 1,200,808 (1,128,637), or an increase of 6.4 percent; in Asia at 695,738 (666,550), an increase of 4.4 percent; and in Africa, at 692,974 (655,755), an increase of 5.7 percent.

The figures suggest that, with the exception of Japan, total registrations increased throughout the world, but that there was a decline in commercial units in use in Great Britain and France.

However, the number of these vehicles actually in use must have been sharply limited by the severe restrictions on the use of motor fuel after the outbreak of the European war.

Germany's Aviation Fuel Position. Oskar Tokayer, in PETROLEUM PRESS SERVICE, Vol. 7 (1940), No. 13, pp. 145-147.

Not having direct access to large resources of high-octane blending gasoline Germany has had to find other means of retaining aerial supremacy in this war. Some important facts remain hidden, but the technical figures are sufficiently clear to allow certain conclusions, especially since supplies of aviation fuel from Roumania are shut off.

In 1938 the German consumption of aviation fuel was about 150,000 tons a year, in terms of 87 octane fuel. From the facts available it appears that Germany now has the means—counting all supplies from coal hydrogenation, available petroleum, benzene, alcohol, etc., of meeting the preferential needs of her military aircraft for 87 octane gasoline on a level considerably above the peace time requirement.

The question of 100 octane fuel is another matter. The supply of mixed octanes from all the German cracking plants cannot exceed 20,000 tons a year. The only other important source is the butane fraction of the gaseous by-products of the Fischer-Tropsch synthesis. This cut is converted to butylenes by catalytic cracking, the butylenes are converted to mixed octenes by catalytic polymerization and then to mixed octanes by hydrogenation. The total capacity of all plants making mixed octanes is about 100,000 tons; when the product is blended with 70-73 octane fuel and treated with tetraethyl lead it may give about 220,000 tons of 100 octane gasoline. By using other available substances such as iso-propyl alcohol and rushing new plants to completion it is probable that 400,0000 tons a year might be attained by the end of 1941, provided that sufficient light gasoline (iso-pentane) were available for blending, but this is not in sight. The end conclusion is that the Germans are going to find it extremely difficult to match the quantities of 100 octane fuel that are available to the Allies, even by drastically restricting the use of ordinary gasoline for other military purposes. On the other hand, if given time enough, by using direct injection pumps instead of carburetors in certain types of aviation engines, a wider range of fuels may be used.

BOOKS

Procedure Handbook of Arc Welding Design and Practice, Sixth Enlarged Edition, issued 1940 by LINCOLN ELECTRIC COMPANY, Cleveland; 1125 pages, 1,557 illustrations; $1.50 U. S., $2.00 foreign.

This encyclopedic handbook on the electric-welding art, previous editions of which are said to have sold around 90,000 copies, now appears in a revised edition containing new facts and data collected by a staff of 200 arc welding engineers representing practically every metal welding industry throughout the world.

The plan of the book is about the same as in previous editions. Aside from the fundamental operations common to all electric welding, the last section, covering 329 pages devoted to typical applications of the art, contains examples selected from the oil industry.

Conversion of Petroleum—A. N. Sachanen; published 1940 by REINHOLD PUBLISHING CORPORATION, 413 pages; $6.00.

The sub-title of this volume is: "Production of Motor Fuels by Thermal and Catalytic Processes", and its author's position is with the research and development division of Socony-Vacuum Oil Co.

The broad problem of the conversion of petroleum into more usable substances is a difficult one to cover and solve in a single handy volume. In realization of this the author admits that a selection had to be made; petroleum history could be neglected, and there would be no great loss if the enormous mass of patent literature were passed by except in cases where patented processes have demonstrated their right by surviving. What is left consists of contributions in the technical and scientific literature that can be regarded as permanent or at least temporarily valuable accretions of knowledge.

After discarding the relatively non-essentials Dr. Sachanen still has enough left to make a valuable text book for the use of students and the working technologists who must make at least an occasional bird's eye view of the whole broad field of petroleum refining. The well established landmarks of this broad field are conspicuously

displayed in the volume before us. The reviewer has not been able to discover that any important refining process that is paying or has up to recently been paying its way in the refining business has been overlooked. The foregoing statement is made without the least implication that the standpoint of the book is empirical. Every step in the conversion of petroleum is based on fundamental chemical and physico-chemical principles with which the refiner must by all means be familiar. Half the book is therefore devoted to fundamentals; thermal and catalytic reactions of hydro-carbons, fundamental factors of cracking, fundamental factors of hydrogenation. With his feet firmly placed on these foundations the reader can survey the large field of cracking equipment and the reasons for its use. In this section all the going processes are described, including those which are on the way out as well as those that are just beginning to come in. The last two-fifths of the space deals with the large subject of cracked gasoline, its nature and chemistry, and how to reduce it to a marketable form. Cracked products other than gasoline receive appropriate attention. The bibliography is extensive and the index is a good one.

Cathodic Protection of Oil Storage Tank Bottoms. Donald H. Bond, in REFINER, vol. 11 (1940), No. 6, pp. 100-102.

Pipe lines apparently are not the only item of oil industry equipment that may benefit from cathodic protection against corrosion. Steel storage tanks are also fit objects for this care under certain circumstances. A 80,000 bbl. tank, for instance has a bottom surface equivalent to that of 6,171 feet of 6-inch pipe, which offers a considerable opportunity for electrolytic corrosion.

The efficacy of cathodic protection for tank bottoms has been shown in various installations during the past three years, for instance at a tank farm situated on the Texas Gulf Coast area; this farm included 45 tanks of 55,000 bbl. capacity each. These tanks had suffered appreciably in the past from external corrosion of the bottoms. An electrolytic survey showed that by establishing a potential-to-ground of at least 0.8 v. negative would afford complete protection. Four units having a rating of 15 v. and 100 amp. each were sufficient for the whole farm. The savings in cost of reconditioning the bottoms at periodic intervals was gratifying.

when ACCURACY counts
LINE SCALE
Delivers!

The LINE SCALE
Packer Special

INSTALL Line Scale, and you get accuracy . . . economy . . . sensitivity . . . durability . . efficiency. This Packer Special model (illustrated) is unsurpassed for all tubing and packer setting work. Weighs to 100,000 lbs. Constantly active. Scale especially adapted for sucker rod and tubing pulling — may be used for drilling not exceeding 50,000 load for tools.

LINE SCALES FOR EVERY NEED

- Packer Junior, 6" dial, net Wt. 19 lbs., 2 sizes, 40,000 and 75,000 lbs. cap.
- Packer Special, 8" dial, net Wt. 36 lbs., 100,000 lbs. cap.
- Conrad, 12" dial, net Wt. 80 lbs., 180,000 lbs. cap.
- Regular Driller, 12" dial, net Wt., 85 lbs., 360,000 lbs. cap.
- Regular Driller, 14" dial, net Wt., 88 lbs., 360,000 lbs. cap.
- Super, 14" dial, net Wt. 91 lbs., 500,000 lbs. cap.

AT YOUR SUPPLY STORE

Line Scale Co. Inc

Phone 2-1765
907-11 S. East 29th P. O. Box 4245
OKLAHOMA CITY, OKLA.

Export Representative
LLOYD G. ENSIGN
30 Rockefeller Plaza, New York, N. Y.

A GRACIOUS HOST FROM COAST TO COAST

IN NEW YORK . .
The Gotham

IN CHICAGO . .
The Drake
The Blackstone

IN LOS ANGELES . .
The Town House

IN BELLEAIR, FLA. .
Belleview Biltmore

A. S. KIRKEBY, Managing Director

KIRKEBY HOTELS

HEAD, WRIGHTSON & Co. LTD.
THORNABY-ON-TEES . . . LONDON . . . SOUTH AFRICA
Iron, Steel and Alloy Steel
Castings for the OIL industry

WORLD OIL PRODUCTION

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified

U. S. BARRELS

	June 1939	July 1939	Aug. 1939	Sept. 1939	Oct. 1939	Nov. 1939	Dec. 1939	Jan. 1940	Feb. 1940	March 1940	April 1940	Preliminary Figures May 1940
United States	104,607,000	110,937,000	80,865,000	108,168,000	114,197,800	111,887,000	114,808,500	113,140,700	108,668,800	120,075,000	116,046,000	119,000,000
Soviet Union[4]	18,700,000	18,200,000	18,100,000	18,000,000	18,406,932[1]	17,813,160[1]	18,406,932[1]	18,406,932[1]	17,251,723[1]	18,454,796[1]	17,896,740[1]	18,448,873
Venezuela	16,430,625	18,015,182	18,743,714	18,652,354	19,516,845	16,681,881	16,050,535	14,798,667	14,380,134	15,514,962	16,675,560[1]	15,722,704
Iran[5]	6,341,652	6,637,503[1]	6,637,503[1]	6,423,390[1]	6,637,503[1]	6,423,390[1]	6,637,503[1]	6,637,503[1]	6,227,895[1]	6,745,073[1]	6,507,180[1]	6,560,000
Netherland India: Sumatra	3,498,094	3,557,020	3,550,123	3,502,437	3,600,371	3,427,490	3,629,655	3,472,786	3,149,536	3,440,792	3,428,880[1]	3,456,624
Borneo	1,154,341	1,156,942	1,111,810	865,693	995,207	1,068,349	1,086,713	1,093,743	1,062,210	1,097,516	1,063,890[1]	1,106,000
Java[9]	514,565	565,181	559,096	511,355	556,658	549,926	633,136	561,064	507,207	562,665	537,720[1]	555,582
Molucca[8]	77,305	73,962	71,767	68,065	64,292	62,340	60,550	59,215	62,340	54,021	67,740[1]	62,310
Roumania	3,684,366	3,902,208	3,945,625	3,795,308	3,842,567	3,743,041	3,842,154	3,786,908	3,595,888	3,818,554	4,422,721	4,002,844
Mexico[13]	3,100,000	3,245,000	3,700,000	4,050,000	4,500,000	3,700,000	3,500,000	3,348,682	3,147,385	3,286,000	3,180,000	3,412,000
Iraq	2,721,992	2,807,402	2,615,129[1]	2,530,770[1]	2,615,129[1]	2,530,770[1]	2,615,129[1]	2,615,129[1]	2,461,723[1]	2,666,713[1]	2,578,020[1]	2,644,362
Colombia	1,851,716	1,798,271	1,950,966	1,894,941	1,860,620	1,918,891	1,871,594	1,924,655	1,767,840[1]	1,895,960[1]	1,841,130[1]	1,903,431
Trinidad	1,575,321	1,620,564	1,636,645[1]	1,583,850[1]	1,636,645[1]	1,583,850[1]	1,636,645[1]	1,636,645[1]	1,529,808[1]	1,633,421[1]	1,580,940[1]	1,634,754
Argentine	1,533,250	1,508,738	1,495,806	1,542,755	1,632,997	1,621,927	1,691,123	1,751,910	1,797,072	1,625,981[1]	1,579,350[1]	1,730,420
Peru[6]	1,051,265	1,100,000[1]	1,100,000[1]	1,116,810[1]	1,154,037[1]	1,116,810[1]	1,154,037[1]	1,154,037[1]	1,071,869[1]	1,139,932[1]	1,097,400[1]	1,143,466
Bahrein[6]	628,812	671,892	698,714	647,595	571,673	563,985	632,962	631,644	581,255	636,577	579,078	622,170
Burma[7]	665 942	650,828	696,317	685,756	710,501	753,771	708,054	666,810[1]	629,039[1]	689,750[1]	666,810[1]	679,530
Canada[7]	821.308	899,169	795,844	720,866	816,257	731,209	502,920	486,859	655,586	570,131	564,570[1]	583,389
Brunei[7]	464,271	490,318	488,777[1]	473,010[1]	488,777[1]	473,010[1]	488,777[1]	488,777[1]	456,576[1]	487,661[1]	471,540[1]	487,940
Great Germany: Old Reich[16]	373,510	391,098	381,114[1]	368,820[1]	381,114[1]	368,820[1]	381,114[1]	381,114[1]	360,383[1]	386,508[1]	371,610[1]	384,183
Ostmark[15]	74,726	85,131	58,869[1]	56,970[1]	58,869[1]	56,970[1]	58,869[1]	58,869[1]	57,072[1]	61,721[1]	61,230[1]	61,194
Slovakia and Moravia	9,000	11,000	11,000[1]	9,810[1]	10,137[1]	9,810[1]	10,137[1]	10,137[1]	9,454[1]	10,106[1]	9,780[1]	10,106
Poland	318,000[1]	330,000[1]	330,000[1]	320,370[1]	331,049[1]	320,370[1]	331,049[1]	331,049[1]	310,155[1]	331,669[1]	320,790[1]	331,421
Japan[16]	221,128	222,072	210,105	222,513	223,016	224,494	223,960[A]	225,308[1]	210,801[1]	224,068[1]	216,960[1]	224,719
British India[11]	137,070	175,932	200,036	212,322	229,422	213,270	228,281	197,532[1]	180,351[1]	189,999[1]	180,090[1]	191,611
Ecuador	193,710	206,868	204,115	193,720	193,382	196,808	205,138	204,509	188,024	211,610	208,513	213,000
Saudi Arabia	382,932	342,558	429,104	538,136	512,590	313,757	437,020	491,663	323,416	606,201	476,359	334,728
Sarawak[12]	104,224	107,961	112,716[1]	109,080[1]	112,716[1]	109,080[1]	112,716[1]	112,716[1]	104,951[1]	112,282[1]	108,330[1]	112,282
Egypt[10]	425,231	436,519	440,678	362,880	420,519	434,174	446,846	438,367	376,043[1]	432,729[1]	454,260[1]	435,891
Italian Empire: Albania[16]	79,931	140,025	89,000[1]	114,540[1]	118,358[1]	114,540[1]	118,358[1]	118,358[1]	112,230[1]	123,411[1]	119,250[1]	121,241
Italy	7,181	6,843	7,600[1]	7,736[1]	7,750[1]	7,500[1]	7,750[1]	7,750[1]	7,250[1]	7,657[1]	7,380[1]	7,668
France	41,000[1]	42,000[1]	42,000[1]	42,653[1]	42,470[1]	41,160[1]	42,532[1]	42,532[1]	39,817[1]	42,439[1]	41,100[1]	42,470
Hungary	67,000[1]	70,000[1]	70,000[1]	65,210[1]	65,317[1]	65,210[1]	65,317[1]	65,317[1]	62,350[1]	67,580[1]	65,580[1]	66,805
Bolovia	8,500[1]	8,700[1]	8,700[1]	7,893[1]	8,556[1]	8,280[1]	8,556[1]	8.556[1]	7,975[1]	8,587[1]	8,310[1]	8,556
Other Countries[17]	48,000	50,700	50,700	50,000	49,073	47,490	49,073	49,073	45,849	49,786	48,150	49,382
WORLD TOTAL	171,832,968	180,464,587	151,408,573	177,915,608	186,599,149	179,182,533	182,683,635	179,405,516	171,400,007	187,261,858	183,482,961	186,351,749

[A] Estimated official sources.
[1] Estimated W. P.
[5] Includes natural gasoline (naphtha) production.
[2] International Petroleum Company and Lobitos Oilfields, Ltd. figures combined.
[4] Russian Saghalin included with U.S.S.R.
[5] Anglo-Iranian Oil Company, Ltd., figures revised —fuel oil returned to the ground has been deducted.
[6] Bahrein Petroleum Company, Ltd., figures.
[7] Does not include Assam or Punjab, which are listed together under British India.
[8] British Malayan Petroleum Company, Ltd., figures.
[9] Includes Madura.
[8] Includes all other Netherland India.

Daily Averages in Barrels

	Jan.—May 1940	Jan.—May 1939
United States	3,795,595	3,435,655
Soviet Union	595,125	590,066
Venezuela	507,184	541,009
Iran	214,984	214,654
Netherland India: Sumatra	111,504	111,204
Borneo	35,680	37,063
Java	17,922	17,740
Molucca	2,010	2,300
Roumania	129,124	126,997
Mexico	107,724	90,285
Iraq	85,302	81,819
Colombia	61,401	58,871
Trinidad	52,734	52,958
Argentine	55,820	50,246
Peru	36,886	38.377
Bahrein	20,070	21,012
Burma	21,920	19,879
Canada	18,819	16,886
Brunei	15,740	15,816
Great Germany: Old Reich	12,393	12,198
Ostmark	1,974	1,608
Slovakia and Moravia	326	321
Poland	10,691	10,709
Japan	7,249	7,322
British India	6,181	6,199
Ecuador	6,747	6,081
Saudi Arabia	14,686	7,005
Sarawak	3,622	3,700
Egypt	14,061	10,840
Italian Empire: Albania	3,911	4,099
Italy	248	258
France	1,370	1,370
Hungary	2,155	2,096
Bolivia	276	276
Other Countries	1,593	1,543
WORLD TOTAL	5,973,040	5,598,090

Official Crude Oil Production Figures for 1933 to 1939 (Revised) in Barrels

	1939	1938	1937	1936	1935	1934	1933
United States	1,264,256,000	1,214,355,000	1,279,160,000	1,098,516,000	996,596,000	908,065,000	905,656,000
Soviet Union	216,727,024	206,192,000	201,856,661	199,635,921	184,008,033	175,635,783	155,596,429
Venezuela	205,783,585	188,429,050	187,675,477	155,270,840	148,809,057	136,098,681	117,113,940
Iran	78,151,332	78,320,840	78,109,001	62,977,950	57,520,488	57,902,092	54,440,075
Netherland India: Sumatra	41,557,020	34,538,128	33,451,511	30,469,428	28,004,595	26,336,011	22,345,172
Borneo	13,125,425	12,812,383	12,960,072	13,068,910	13,529,185	14,335,543	15,003,175
Java	6,568,660	6,955,283	7,152,931	3,618,293	3,462,440	3,778,920	3,600,816
Molucca	836,144	607,622	537,436	375,823	311,872	273,698	285,335
Roumania	45,931,846	48,366,000	52,395,725	63,532,846	61,270,072	61,849,306	53,919,708
Mexico	39,428,141	38,505,824	46,455,687	41,027,915	40,240,563	38,171,946	34,000,830
Iraq	30,791,132	32,404,000	30,603,660	29,913,150	27,410,983	7,639,849	1,094,915
Colombia	22,036,613	21,581,588	20,297,543	18,756,110	17,597,655	17,337,900	13,156,126
Trinidad	19,270,256	17,736,176	15,502,989	13,237,030	11,671,224	10,894,363	9,561,353
Argentine	18,613,167	17,076,237	16,354,717	15,457,960	14,297,025	14,021,901	13,690,556
Peru	13,587,906	15,908,279	17,459,112	17,593,069	17,056,555	16,314,381	13,257,318
Bahrein	7,588,554	8,297,998	7,762,264	4,644,635	1,264,807	285,072	31,377
Burma	7,872,981	7,499,498	7,847,553	7,587,718	7,181,113	7,278,859	7,114,311
Canada	7,837,503	6,965,457	2,996,033	1,507,931	1,447,204	1,410,895	1,145,333
Brunei	5,755,164	5,387,214	4,397,038	3,296,938	3,302,905	2,705,350	2,035,656
Great Germany: Old Reich	4,487,491	3,850,044	3,148,300	3,076,858	2,967,438	2,204,402	1,656,602
Ostmark	693,247	370,038	221,266	50,092	44,347	27,965	5,765
Slovakia and Moravia	119,380	132,005	123,474	126,603	136,580	177,797	121,695
Poland	3,898,044	3,828,438	3,799,862	3,869,575	3,901,881	4,011,336	4,174,079
Japan	2,652,930	2,511,184	2,487,841	2,403,072	2,294,878	1,872,837	1,504,412
British India	2,332,467	2,330,209	2,161,653	1,978,329	2,037,810	1,921,863	1,628,803
Ecuador	2,312,118	2,257,278	2,161,436	1,942,467	1,731,785	1,636,619	1,619,902
Saudi Arabia	3,933,904	495,135	64,968	19,777	Nil	Nil	Nil
Sarawak	1,327,327	1,624,882	1,655,565	1,547,882	1,776,593	1,942,591	2,206,815
Egypt	4,602,797	1,561,231	1,163,267	1,262,666	1,255,151	1,527,252	1,653,535
Italian Empire: Albania	1,393,727	437,597	380,292	219,693	41,218	17,500	11,437
Italy	91,330	106,083	112,700	129,653	128,615	162,449	213,534
France	500,815	516,240	507,067	534,063	529,664	700,000	786,366
Hungary	769,092	330,829	13,910	100	Nil	Nil	Nil
Bolivia	100,885	106,620	123,123	104,746	163,295	157,875	111,973
Other Countries	578,036	243,000	70,000	37,100	32,300	64,000	54,100
WORLD TOTAL	2,075,512,043	1,982,639,390	2,041,170,134	1,797,791,150	1,652,023,331	1,516,760,036	1,438,797,443

PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

METRIC TONS

	June 1939	July 1939	Aug. 1939	Sept. 1939	Oct. 1939	Nov. 1939	Dec. 1939	Jan. 1940	Feb. 1940	March 1940	April 1940	Preliminary Figures May 1940
United States	14,153,000	15,009,700	10,941,000	14,635,096	15,450,953	15,138,276	15,533,757	15,307,901	14,702,854	16,246,164	15,700,987	16,100,662
Soviet Union[4]	2,590,000	2,500,000	2,480,000	2,300,000	2,508,024[1]	2,427,120[1]	2,508,024[1]	2,508,024[1]	2,360,194[1]	2,531,522[1]	2,436,780[1]	2,520,021
Venezuela	2,439,598	2,674,860	2,783,031	2,769,466	2,897,824	2,476,894	2,383,153	2,197,278	2,135,135	2,303,632	2,475,930[1]	2,334,455
Iran[5]	841,248	880,493[1]	880,493[1]	852,090[1]	880,493[1]	852,090[1]	880,493[1]	880,493[1]	826,152[1]	894,753[1]	863,190[1]	870,212
Netherland India: Sumatra	447,842	455,386	454,503	448,398	460,936	438,803	464,685	444,602	403,218	440,506	438,960[1]	432,525
Borneo	147,784	148,117	142,339	110,830	127,411	136,775	139,126	140,026	135,989	140,509	136,290[1]	141,608
Java[3]	65,877	72,357	71,578	65,466	71,266	70,404	81,057	71,830	64,935	72,035	68,820[1]	71,114
Molucca[*]	9,897	9,469	9,188	8,842	8,231	7,981	7,752	7,581	7,981	6,916	8,670[1]	7,967
Roumania	499,575	529,113	535,000	514,618	521,026	507,531	520,970	513,479	487,578	517,770	599,691	542,748
Mexico[2]	455,212	476,505	543,316	594,713	660,973	543,318	513,950	492,094	462,171	482,525	466,960	501,028
Iraq	363,854	375,271	349,556[1]	338,280[1]	349,556[1]	338,280[1]	349,556[1]	349,556[1]	330,034[1]	356,531[1]	344,670[1]	353,741
Colombia	258,258	247,017	272,101	264,287	257,920	267,627	260,524	268,431	246,094[1]	263,872[1]	256,200[1]	265,050
Trinidad	221,564	227,927	230,206[1]	222,780[1]	230,206[1]	222,780[1]	230,206[1]	230,206[1]	215,151[1]	229,710[1]	222,360[1]	229,896
Argentine	218,411	214,919	213,077	219,765	232,620	231,043	240,900	249,559	255,993	231,601[1]	224,970[1]	246,481
Peru[3]	138,782	146,000[1]	146,000[1]	147,810[1]	152,737[1]	147,810[1]	152,737[1]	152,737[1]	141,810[1]	150,784[1]	145,200[1]	151,280
Bahrein[6]	85,665	91,551	95,348	87,030	78,012	76,963	86,375	86,195	79,319	87,017	79,022	84,940
Burma[7]	91,980	89,893	96,176	94,717	98,135	104,112	97,797	92,101[1]	86,855[1]	94,147[1]	91,980[1]	93,527
Canada[8]	104,518	114,427	101,278	91,736	103,875	93,052	64,001	61,957	83,429	72,554	71,820[1]	74,214
Brunei[9]	61,935	65,410	65,193[1]	63,090[1]	65,193[1]	63,090[1]	65,193[1]	65,193[1]	60,900[1]	65,038[1]	62,880[1]	65,069
Great Germany: Old Reich[14]	53,412	55,927	58,300[1]	53,190[1]	54,963[1]	53,190[1]	54,963[1]	54,963[1]	51,997[1]	55,800[1]	53,940[1]	55,490
Ostmark[15]	11,289	12,691	13,000[1]	9,030[1]	9,331[1]	9,030[1]	9,331[1]	9,331[1]	9,048[1]	9,827[1]	9,780[1]	9,703
Slovakia and Moravia	1,400	1,600	1,600[1]	1,550[1]	1,519[1]	1,470[1]	1,519[1]	1,519[1]	1,421[1]	1,519[1]	1,470[1]	1,519
Poland	41,000[1]	45,000[1]	45,000[1]	42,960[1]	44,392[1]	42,960[1]	44,392[1]	44,392[1]	41,644[1]	44,516[1]	43,050[1]	44,454
Japan[10]	31,454	31,544	31,721	31,651	31,723	31,933	31,857[A]	32,178[1]	30,131[1]	32,023[1]	31,020[1]	32,085
British India[11]	18,932	24,300	27,629	29,326	31,688	29,457	31,530	27,280[1]	24,911[1]	26,226[1]	24,870[1]	26,443
Ecuador	25,539	27,272	26,910	25,540	25,495	25,947	27,045	26,962	24,788	27,898	27,490	28,081
Saudi Arabia	41,037	46,404	58,129	72,899	72,899	42,503	59,201	66,604	43,812	82,120	64,531	45,344
Sarawak[12]	13,329	13,797	14,539[1]	14,070[1]	14,539[1]	14,070[1]	14,539[1]	14,539[1]	13,543[1]	14,415[1]	13,920[1]	14,446
Egypt[13]	60,730	62,342	62,936	51,810	60,057	62,150	63,817	62,606	53,534[1]	58,125[1]	57,150[1]	59,272
Italian Empire: Albania[16]	11,980	20,987	13,000[1]	17,100[1]	17,670[1]	17,100[1]	17,670[1]	17,670[1]	16,762[1]	18,415[1]	17,790[1]	18,073
Italy	892	850	950[1]	961[1]	961[1]	930[1]	961[1]	961[1]	899[1]	930[1]	900[1]	930
France	5,700[1]	6,000[1]	6,000[1]	5,760[1]	5,952[1]	5,760[1]	5,952[1]	5,952[1]	5,568[1]	5,952[1]	5,760[1]	5,952
Hungary	9,000[1]	9,500[1]	9,500[1]	8,490[1]	8,773[1]	8,490[1]	8,773[1]	8,773[1]	8,381[1]	9,052[1]	8,760[1]	8,928
Bolivia	1,000[1]	1,000[1]	1,000[1]	960[1]	992[1]	960[1]	992[1]	992[1]	928[1]	992[1]	960[1]	992
Other Countries, [17]	6,700	7,100	7,100	7,000	6,975	6,750	6,975	6,975	6,525	7,006	6,780	7,223
WORLD TOTAL	23,528,394	24,694,749	20,786,697	24,201,311	25,543,320	24,496,649	24,959,773	24,500,940	23,419,684	25,582,402	25,063,551	25,445,473

[2] Japanese Saghalin, Taiwan (Formosa) and Hokkaido included with Japan.
[11] Excluding Burma.
[12] Sarawak Oilfields, Ltd., figures.
[A] Estimated Official Sources
[13] Anglo-Egyptian Oilfields, Ltd., figures.
[14] Prussia, Thuringia and Baden.
[15] Formerly known as Austria.
[16] Italian imports of Albanian crude oil.
[*] Includes all other Netherland India.
[17] Estimate representing Morocco, Cuba, New Zealand, Barbados, Greece, Algeria, Yugoslavia, Australia, Great Britain, Kuweit and China.
[18] Official Figures—Petroleos Mexicanos.

Daily Averages in Metric Tons

	Jan.—May 1940	1939
United States	513,543	464,842
Soviet Union	81,291	80,907
Venezuela	75,305	80,191
Iran	28,518	28,474
Netherland India: Sumatra	14,209	14,236
Borneo	4,568	4,790
Java	2,294	2,271
Molucca	257	296
Roumania	17,508	17,219
Mexico	15,820	13,286
Iraq	11,411	10,937
Colombia	8,550	8,210
Trinidad	7,416	7,449
Argentine	7,951	7,150
Peru	4,880	5,077
Bahrein	2,740	2,864
Burma	3,017	2,745
Canada	2,394	2,149
Brunei	2,099	2,110
Great Germany: Old Reich	1,790	1,774
Ostmark	313	239
Slovakia and Moravia	49	49
Poland	1,434	1,438
Japan	1,035	1,041
British India	853	856
Ecuador	889	815
Saudi Arabia	1,989	948
Sarawak	466	479
Egypt	1,912	1,547
Italian Empire: Albania	583	614
Italy	30	32
France	192	192
Hungary	288	270
Bolivia	32	33
Other Countries	226	223
WORLD TOTAL	815,868	765,774

Official Crude Oil Production Figures for 1933 to 1939 (Revised) in Metric Tons

	1939	1938	1937	1936	1935	1934	1933
United States	171,053,443	164,346,325	172,822,797	148,707,864	134,912,143	122,913,903	122,601,191
Soviet Union	29,530,168	28,859,000	27,867,025‡	27,384,900	25,241,100	24,092,700	21,330,100
Venezuela	30,533,706	27,845,286	27,733,926	22,945,299	21,990,373	20,112,115	17,293,193
Iran	10,367,112	10,358,495	10,330,480	8,329,289	7,607,500	7,657,970	7,200,093
Netherland India: Sumatra	5,320,320	4,662,836	4,490,137	4,114,710	3,759,006	3,535,035	2,999,352
Borneo	1,680,377	1,719,783	1,739,607	1,773,545	1,815,998	1,924,234	2,013,849
Java	840,950	933,595	960,125	499,097	464,757	510 320	483,331
Molucca	107,047	81,560	72.139	50,446	41,862	36 738	38,300
Roumania	6,228,047	6,603,000	7,153,000	8,704,000	8,394,000	8,473,355	7,387,000
Mexico	5,794,215	5,716,423	6,896,657	6,090,842	5,973,955	5,666,857	5,049,109
Iraq	4,115,845	4,345,000	4,126,185	4,079,066	3,724,231	1,048,108	147,943
Colombia	3,067,568	3,007,935	2,844,251	2,614,092	2,452,635	2,416,432	1,833,606
Trinidad	2,710,515	2,472,943	2,181,676	1,862,796	1,642,446	1,533,122	1,345,532
Argentina	2,651,448	2,432,857	2,330,063	2,202,304	2,036,903	1,997,706	1,950,499
Peru	1,798,557	9,099,885	2,313,691	2,331,454	2,260,903	2,161,990	1,756,867
Bahrein	1,033,472	1,130,734	1,058,557	635,555	173,072	39,008	4,293
Burma	1,087,424	1,039,960	1,083,391	1,047,593	991,456	1,004,951	982,233
Canada	997,391	879,921	378,478	190,495	182,820	178,233	144,686
Brunei	767,700	707,123	576,545	470,991	471,842	386,478	290,808
Great Germany: Old Reich	647,337	552,074	453,451	444,600	427,400	317,500	238,600
Ostmark	109,904	63,468	33,010	7,473	6,616	4,172	860
Slovakia and Moravia	18,103	19,282	18,036	18,665	19,946	25,971	17,776
Poland	522,874	504,678	501,301	510,630	614,760	529,200	550,670
Japan	379,161	356,328	341,040	341,976	326,580	266,520	212,667
British India	322,160	322,125	298,450	273,137	281,072	265,341	224,879
Ecuador	306,824	319,877	306,326	275,293	245,434	231,947	229,578
Saudi Arabia	536,366	66,683	8,070	2,447	Nil	Nil	Nil
Sarawak	171,322	200,126	217,085	221,126	253,799	277,513	315,259
Egypt	657,510	223,058	166,298	177,491	176,436	214,671	232,437
Italian Empire: Albania	208,279	65,313	56,760	32,760	6,152	2,500	1,707
Italy	11,346	13,178	14,000	16,106	15,977	20,180	26,526
France	70,224	72,106	71,008	74,788	74,172	98,025	110,120
Hungary	103,364	42,798	13,910	13	Nil	Nil	Nil
Bolivia	11,904	13,262	15,487	13,197	20,540	19,858	14,085
Other Countries	82,300	34,080	10,000	5,300	4,600	9,100	7,700
WORLD TOTAL	283,844,283	279,111,097	279,482,962	246,449,340	226,610,486	207,971,753	197,034,849

Fluid Couplings

(Continued from page 85)

the equipment described has decided that future rigs of this type will be powered with three 240 h.p. Diesels which will make 720 h.p. available for pulling and 480 h.p. available for the pumps. All three engines will be exactly alike and interchangeable. They will be connected in such a manner that, by use of compound drive chains, any one of the engines can be shut down for repairs without interfering with the operation of the rig.

The use of three 240 h.p. Diesels will enable the operator to increase pump size from 7¼ by 16 in. to 7¾ by 18 in. Investigations are now being carried on to eliminate the countershafts for the draw works and for the pumps and to arrange the necessary drives direct from the extended engine crankshafts. It is hoped thereby to curtail much of the bulk and to shorten the time now necessary for rigging up. Speed in rigging up will also be increased by doing away with the present concrete foundations and unitizing the entire rig by use of steel cross members. Finally the future installations in this section will be provided with independent rotary drive permitting higher rotational speed of the drilling string.

Fluid couplings played an important part in the decision to use straight Diesel type hook-ups in this particular section. It was felt that even Diesel electric, much less straight Diesel drive, does not possess the flexibility and simplicity of steam and that if transportation of water and fuel permitted, steam would be the ideal drive. Of course, ample water—occasionally too much—is readily available in the East Indies. Nevertheless, fuel supply presented a problem due to transport difficulties. Despite the higher upkeep of the more complicated Diesel rig, it was found that, with Diesel fuel consumption of the order of 1/15th to 1/20th. that of steam rigs, sufficient economies in transportation were possible to justify the slightly higher upkeep. Diesel fuel could be transported in drums to the drilling location eliminating the necessity of a costly pipeline from a nearby terminal.

As to the choice between Diesel electric and straight Diesel, the former was felt to offer greater flexibility and on that basis to be the more desirable. Against this was the higher cost due to the more complicated nature of the machinery. It would be necessary to keep on the location at all times an expert electrician as well as an expert Diesel mechanic. The deciding factor, however, was the fact that practically equal flexibility could be obtained with the fluid coupling on the straight Diesel, thereby minimizing one of its principal drawbacks. In order to obtain the maximum flexibility with straight Diesel drive, even when using fluid couplings, engine governors with a large speed range were provided. The engines may now be regulated for speeds from 800 down to 200 r.p.m., enabling the operator to take full advantage of the flexibility inherent in the fluid coupling.

20,000 feet?

Baroid Service Engineer testing mud at the well.

Part of the research laboratories at Los Angeles.

Portion of testing and research departments in Tulsa laboratory.

Section of the Houston laboratory.

MUD SELECTION AND CONTROL VITALLY IMPORTANT IN WELLS OF GREAT DEPTH

For more than a decade, Baroid's engineering progress in mud control has kept pace with the mechanical developments in the oil industry. This progress has helped to eliminate drilling difficulties to such an extent that wells of great depth are now normally drilled with fewer troubles than were originally encountered in wells of shallow depth. • The selection of suitable drilling mud and its careful control constitutes one of the most important factors pertaining to trouble-free drilling. • You can *speed up with safety* and *drill more economically* with Baroid Products and service. This has been *proved* in thousands of wells.

15,004 ? 20,000

BAROID PRODUCTS

BAROID & COLOX-Extra Heavy Drilling Muds. • AQUAGEL-Trouble-Proof Colloidal Drilling Mud. • STABILITE-An Improved Chemical Mud Thinner. • FIBROTEX-For Preventing or Regaining Lost Circulation. • AQUAGEL for CEMENT-For Setting Casing and Restoring Lost Circulation. • SMENTOX-For Reconditioning Cement-Cut Muds. • ZEOGEL-Special Clay to be Used as a Suspending Agent When Salt or Salt Water is Encountered. • TESTING EQUIPMENT-For Drilling Mud Analysis and Control. BAROID WELL-LOGGING SERVICE-Formation Information Through Mud Analysis.

BAROID SALES DIVISION
National Lead Company
BAROID SALES OFFICES
LOS ANGELES • TULSA • HOUSTON

BAROID OIL WELL DRILLING MUD SERVICE

RENOLD

Designed and made to A. P. I. specification by the world's leading driving chain makers.
Send for leaflet No. 216/32
THE RENOLD & COVENTRY CHAIN CO. Ltd.
MANCHESTER, ENGLAND
Agents throughout the world

LEACH EXCHANGERS
for
High Temperatures
High Pressures

Fracto Control

High Heat Transfer
Low Vapor Pressure Drop
Long Tube Life
Easy Cleanability

Leach Exchangers are fully protected by U. S. and foreign patents

C. H. LEACH CO.
117 Liberty St. New York